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Communications in Computer and Information Science 1779

Higher Education Learning Methodologies and Technologies Online

4th International Conference, HELMeTO 2022
Palermo, Italy, September 21–23, 2022
Revised Selected Papers

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Communications in Computer and Information Science 1779

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Preface

This volume of Communications in Computer and Information Science (CCIS) contains the post-proceedings of HELMeTO 2022, the fourth International Conference on Higher Education Learning Methodologies and Technologies Online, which took place during September 21–23, 2022 in Palermo, Italy.

The conference was organized by the Department of Mathematics and Computer Science at the University of Palermo and by the Institute of Educational Technology of the National Research Council of Italy. The 2022 edition of HELMeTO also marked the return of the event in presence, as the previous two editions had been held entirely online due to the Covid-19 emergency.

The growing interest in the topics of learning methodologies and technologies in higher education, and in particular in the interdisciplinary approach that characterizes this research field, suggested a change from a workshop format to a conference event, thus promoting a more international perspective. The success of this approach was highlighted by the 126 submissions received (almost double those received for the previous event) from more than 400 authors in 24 countries.

These numbers not only confirm the growth trend of an event that was born just four years ago (39 submissions in 2019, 59 in 2020, and 65 in 2021), but above all they consecrate HELMeTO as a key event for researchers and practitioners working in Higher Distance Education Institutions or studying Online Learning Methodologies to present and share their research in a multidisciplinary and international context.

The conference included two general tracks on Online pedagogy and learning methodologies and and on Learning technologies, data analytics and educational big data mining as well as their applications. Thanks to the growing attention that the conference has attracted over the years, this edition collected twelve special tracks, focusing on specific topics, previously proposed by their organizers and peer-reviewed by the Program Committee.

- Special Track 1 - Improving education via XR and AI
- Special Track 2 - Educational Approaches and Innovative Applications to Counteract Social Media Threats
- Special Track 3 - Hybrid Learning and Accessibility in higher education
- Special Track 4 - E-learning for providing "augmented" mathematics education at University level
- Special Track 5 - STEAM Education old and new challenges in distance teaching/learning approaches in Higher Education
- Special Track 6 - Online Faculty Development: Next Steps for Practice and Future Research
- Special Track 7 - Artificial Intelligence and Multimodal Technologies in Education (AI&MTEd '22)
- Special Track 8 - Experience-based training activities for online higher education
- Special Track 9 - Intelligent Analytics for Process-aware Higher Education

- Special Track 10 - The digital innovation of university teaching observed through the prism of emotions
- Special Track 11 - Empowering soft skills and digital competencies in higher education
- Special Track 12 - Manufacturing Education for a Sustainable fourth industrial revolution

An international Program/Scientific Committee with members from 17 countries (Austria, China, Cyprus, Ecuador, France, Germany, Greece, Italy, Morocco, Palestine, Portugal, Slovakia, Spain, Sweden, Turkey, UK, USA) was in charge of peer-reviewing the 126 papers submitted to HELMeTO 2022; 105 papers were selected for presentation at the conference. A final set of the best 59 papers (47% of the original submissions) were selected and extended for publication in this book after a separate double-blind peer-review process performed by at least three members of the Program/Scientific Committee.

We thank all the authors for their contributions and presentations, for their efforts, and for their presence at the event. Similarly, we would like to thank all the committee members, organizers, and contributors, for their involvement and help in the process of preparing and hosting both the conference and this book. Our thanks go also to the University of Palermo and the Institute of Educational Technology of the National Research Council of Italy and to SIREM (Società Italiana di Ricerca sull'Educazione Mediale).

February 2023

Giovanni Fulantelli
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Learning Methodologies and Technologies Online. HELMeTO 2022 Editorial: Introduction to the Scientific Contributions (Editorial)

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Keywords: Distance learning · Virtual learning environment · Online learning · eLearning

The HELMeTO 2022 Conference combined methodology, innovation, and technology. These three pillars represent the key to making significant progress in the educational world, specifically for this conference, in the university sector. But these are three pillars that must work in an integrated way. Coordination is essential and, above all, sensitivity to understand that in online and hybrid learning there are not such hard divisions. While it is true that the focus can be on methodology, innovation or technology, it is also true that they feed each other and that only through a joint work they could have a significant impact on both, the educational process, and the user performance. The proceedings book that we introduce following reflects significant contributions through almost 60 chapters. Making the division according to the tracks of the conference (2 general tracks and 12 special tracks) would have been something long and not especially effective. That is why we have clustered them by the main foci of each chapter. Taking into account that the three foci that we have commented before are interwoven, there is always a primary one and that is the one we have used to adhere the chapters to one section or another. We show, therefore, three sections focused on 1) general aspects; 2) methodology and education; and 3) technology and digital environment. Each chapter should be considered as a contribution about one of the main foci but which, without a doubt, considers the others.

Contributions on General Aspects of Online Higher Education

The shift towards online learning for higher education has brought forth a number of general issues such as lack of interaction, technical difficulties, and reduced opportunities for hands-on learning. However, the COVID-19 pandemic has accentuated the need for universities to adapt to this mode of education delivery [1]. In response, online pedagogy and learning methodologies have evolved to address these challenges, such as incorporating more interactive and engaging activities and leveraging learning technologies like virtual reality and simulations [2]. Furthermore, the use of data analytics and educational big data mining has become increasingly important in improving the online learning experience. These technologies allow for the collection and analysis of vast amounts of data about student learning and behavior, enabling universities to make informed decisions about curriculum design, student support, and the use of educational technology [3]. The application of these tools has the potential to enhance the overall effectiveness of online learning and provide a more personalized educational experience for students [4]. These general issues on online learning for higher education are covered by the chapters included in this section of the book.

Contributions on the Methodology and Pedagogical Issues in Online Higher Education

The use of technology and digital tools has dramatically changed the way education is delivered, making it necessary to evaluate the relationship between methodology and education in this context [5]. In online higher education, the combination of these two elements is crucial in ensuring that students receive an engaging and effective learning experience. The development of appropriate and effective methodologies is critical in online education as it directly impacts the quality of teaching and learning outcomes. Furthermore, the use of technology has created new opportunities for innovative methodologies to be employed in online higher education. The goal of these methodologies should be to facilitate active student engagement and interaction, and to enhance the development of critical thinking and problem-solving skills. The chapters that we present in the Methodology and Education section cover some of the key aspects of the methodological and pedagogical issues in online higher education. One of the aspects of online learning that has gained significant momentum, since the end of the Covid emergency, concerns hybrid approach to learning, combining online and face-to-face instructions. This approach not only increases accessibility for students, but also enhances the learning experience by incorporating the benefits of both modalities. Experience-based training activities, such as virtual simulations and hands-on projects, can also enhance the online learning experience and provide students with practical skills that can be applied in real-world situations. Furthermore, empowering soft skills and digital competencies in higher education is essential in preparing students for the digital age. By integrating these skills into the curriculum, students can develop the necessary competencies to thrive in a rapidly changing, technology-driven world. STEAM education (Science, Technology, Engineering, Arts, and Mathematics) is another key concept for our discourse, due to the fact that well-designed online education methodologies can enable particularly effective STEAM education processes [6]. Online learning has revolutionized the way education is delivered and has made education more accessible to a wider audience. However, it has also brought new challenges, such as the threat of social media distractions and cyberbullying, which can negatively impact the learning experience. A number of chapters in this book illustrate innovative applications to counteract social media threats. Finally, as online education continues to evolve, faculty development programs play a crucial role in supporting the transition to online learning and ensuring that educators are equipped with the necessary skills and knowledge to deliver effective online instruction.

Contributions on the Technological and Digital Issues in Online Higher Education

Technology and the digital environment are a key tool for progress in online learning, online teaching, and online academic management [7]. Let us not forget that, although the usual speech is focused on learning, both teaching and management are key to producing a useful and interlaced ecosystem between all the actors involved in an educational process. We achieve through a well-integrated technology, a reflection of a digital society. And with a digital sensitivity such as the one we enjoy right now in much of the world, we can make use, distribution and production of resources, methodologies, assessments, analysis, predictions, and endless services to actively and positively influence the educational process. Let us not forget that technology is nothing more than a tool, and that what really makes the difference is what we do with it. That is why this section is meaningless without the other two sections, both on methodology and education, and on general and transversal aspects. A good strategy, well implemented, supports any tool. A good technology without a strategy is yet an empty device. The chapters that we present in this section of technology and digital environment talk about significant advances and effective technology-based approaches, such as artificial intelligence, augmented reality, data analysis, digital innovation, and a long etcetera. We should read between the lines to understand that all of them constitute fundamental actors in an online or hybrid environment. Further, and inevitably, they must be applied in a sensitive way, and with educational standards of the highest quality.

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Contents

Methodology and Education

General

The Psychological Impact of Online Learning During the COVID-19 Pandemic. A Survey on a Sample of Italian Undergraduates

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Abstract. The COVID-19 pandemic created a risk to all educational system levels, ranging from primary to university grades, due to social restriction measures of isolation worldwide.

Switching from the traditional educational system to Online Learning (OL) was challenging for many undergraduates due to the lack of Internet connectivity or digital devices and a suitable home study environment. Therefore, a survey study on a sample of 1069 undergraduates (78.5% female; Mage = 21.72; SD = 4.05) investigated the interrelation among psychological skills for managing learning habits and strategies, academic achievement, social interaction, and mental health problems during the COVID-19 pandemic was performed. Results showed a significant effect of the COVID-19 pandemic on study variables related to online learning due to individual differences in self-efficacy, academic motivation, and anxiety. Moreover, university students reported higher physical and mental health problems since the COVID-19 pandemic has had a significant psychological impact.

Keywords: Online Learning · university students · Self-efficacy · Trait anxiety · Mental Health · COVID-19

1 Introduction

The COVID-19 pandemic created a risk to all educational system levels, ranging from primary to university grades, due to social restriction measures of isolation worldwide [1]. Online Learning (OL) was challenging for many university students because of the lack of Internet connectivity or digital devices and a suitable home study environment [2]. Uncertainty, plan modification, and delays in the graduation and post-graduation plans timeline are reported by literature [3] and lower scores in the final examinations, especially in all students with low Internet connectivity or limited access to devices [4, 5].

A recent review study about the COVID-19 pandemic on university students reports a significant impact on mental health with increasing stress levels, anxiety, and depressive symptoms because of changed delivery and uncertainty of university education, technological concerns of online courses, being far from home, social isolation, decreased

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family income, and future employment [6]. It must be noted that these impacts have been observed in universities across the world [7]. During the COVID-19 pandemic, anxiety had the highest prevalence among mental health disorders among university students [8].

To better understand the negative consequences of the COVID-19 pandemic on mental health, scholars investigated psychological variables that could predict or prevent developing anxiety or depression, such as self-efficacy and academic motivation.

Self-efficacy, which refers to beliefs in one's capabilities to organize and execute all actions required to produce given attainments, seems to be a strong predictor for mental health in a sample of 3190 Turkish [9]. Self-efficacy beliefs are also strongly associated with the negative effect of the COVID-19 pandemic on individuals' goal pursuits. People with low self-efficacy beliefs from before to during the pandemic were unsure or did not believe they could still carry out their goals and either abandoned or were uncertain they could pursue their goals [10]. Significant associations between self-efficacy and perceived ineffectiveness of OL are reported, too [11].

Another crucial psychological variable that seems to affect the OL of students during the COVID-19 pandemic is academic motivation. As defined in the theoretical framework of Self-Determination Theory [12], academic motivation refers to the individual level of regulation and self-determination to pursue an academic goal. It ranges along a continuum from intrinsic motivation to amotivation alongside six different forms of motivation – i.e., intrinsic regulation, integration, identification, introjection, external regulation, and amotivation. They are categorized into two main groups: *autonomous* – i.e., intrinsic, integrated, and identified motivation – and *controlled*– i.e., introjected, external, and amotivation, respectively. In detail, intrinsic motivation drives people to attain personal aims such as enjoyment, curiosity, satisfaction, and interest. Integrated motivation drives people to pursue goals related to an individual's self and unique value system, whereas identified motivation pursues behaviors acknowledged for their underlying benefits. Introjected motivation drives behaviors moved by external sources internalized, and external regulation drives behaviors entirely moved by external causes. Finally, amotivation drives behaviors categorized by lack of intention or interest in the activity. A recent study compared two samples of Italian and Portuguese children in grades 1 to 9 involved in OL activities during the COVID-19 pandemic and found a decrease in students' academic motivation in Italy and Portugal, although higher in Italian students. Results also indicated that students with low levels of academic motivation also decreased participation in extracurricular activities [13]. Similar associations between academic motivation and COVID-19 distress are reported in a sample of undergraduate students who also decreased their sense of belonging to their university [14].

In Italy, university institutions switched to OL in March 2020, in the middle of the semester, with multiple direct consequences for students forced not to attend classes and laboratories physically and limited the traditional face-to-face contact with their teachers and between themselves.

The present paper aims to describe the impact of OL during the COVID-19 pandemic on a sample of undergraduates considering their psychological profiles and a series of variables related to their OL activities, such as learning habits and strategies, and their academic achievement.

In the literature, most studies compared the effectiveness of OL with face-to-face learning activities showing that specific learning strategies are necessary to enhance students' quality of interactions in OL systems. For example, students must apply strategies to identify relevant information, process information and learning materials, keep learning on track, organize learning and materials, and avoid internal and external distractions [15]. Compared to traditional classrooms, the OL is more suitable for self-regulated students who can do synergic actions of thoughts, feelings, and efforts to plan and achieve personal learning goals [16]. Furthermore, recent studies show that during the COVID-19 pandemic, university students often obtained lower scores in the final examinations, especially in all those cases of students having problems at home with Internet connectivity or limited access to devices [4].

The study measured students' mental health troubles and requests for help during the COVID-19 pandemic since these variables have had little attention to date [4, 17].

A survey performed on a sample of undergraduate students participating in the OL activities during the COVID-19 s-wave Italian lockdown phase in March-May 2021 was designed to gain these aims.

2 Method

Participants

A total sample of 1028 undergraduates attending courses for the first-level degree participated in the survey.

Table 1 shows the socio-demographic composition of our sample. Specifically, our sample is mainly composed of female (78.4%) in-course students (96.2%) attending the first year of bachelor's degree courses (60.5%) in the humanities area (59.6%) with a mean age of 21.10 years (SD = 2.45). In addition, during the COVID-19 social restriction measures, a high percentage of students lived in big city apartments (48.8%), but a minority were in small city areas (26%), even if all were with their parents (94.1%).

Table 1. Socio-Demographic Composition of the total sample of university students (N = 1028)

	%
Gender	
F	78.4
M	21.6
Degree Course	
Bachelor	60.5
Master	0
5-years Course	39.5
Status	

(*continued*)

Table 1. (*continued*)

	%
In-Course	96.2
Outside-Course	3.8
Areas	
Arts	1.1
Linguistic	6.1
Professional	13.6
Scientific	4.7
Technical	15.1
Humanities	59.6
Types of dwelling	
City Apartment	48.8
Country or Beach House	9.2
Flat with a garden home in cities with < 60,000 citizens	10.1
Apartments in cities with < 60,000 citizens	26.0
Townhouse with garden home	4.3
Country or Beach Apartment	1.6

Psychological Assessment

All participants were assessed using the following psychological measures:

***General Self-efficacy Scale* (Italian version) [18]**

The scale is a self-report measure of self-efficacy. It is a ten-item scale with good internal reliability (Cronbach's alphas between .76 and .90) and validity. It positively correlates with emotion, optimism, and work satisfaction and negatively with depression, stress, health complaints, burnout, and anxiety. Each item is rated on a 4-point scale with anchors 1: Not at all true and 4: Exactly true. The total score was computed for each scale by finding the sum of all items. For general self-efficacy, the total score ranges between 10 and 40, with a higher score indicating a more general self-efficacy. In the present study, the standardized Cronbach's α coefficient of general self-efficacy was .842, in line with the literature [18].

***Academic Motivation Scale* (AMS- Italian version) [16]**

The AMS measures intrinsic, extrinsic motivation, and amotivation across many academic disciplines as defined in the light of Self-Determination Theory [19]. In the present study, the Italian version of the AMS, provided by [20] was used, consisting of five subscales, each of four items rated on a 4-point scale with anchors 1: Not at all true and 4: Exactly true, and measuring Amotivation (e.g., *Honestly, I don't know; I really feel that I am wasting my time in school*; Cronbach's $\alpha = .86$), External Regulation (e.g., *To obtain a more prestigious job later on*; Cronbach's $\alpha = .83$), Introjected Regulation (e.g., *Because when I succeed in school, I feel necessary*; Cronbach's $\alpha = .85$), Identified regulation (e.g., *Because I think that a high-school education will help me better prepare for the career I have chosen*; Cronbach's $\alpha = .81$), and Intrinsic Regulation (e.g., *Because*

I experience pleasure and satisfaction while learning new things; Cronbach's α = .87). Following the indication provided by a recent meta-analysis about the Academic Motivation Scale scoring method [21], it was computed the Relative Autonomy Index (RAI) to measure the person's overall motivational orientation. RAI positive scores represent more autonomous regulation, and negative scores define more controlling regulation. Different weights to each Academic Motivation Scale subscale's score were assigned, computing the following formula:

RAI = (+2*Intrinsic Motivation subscale score) + (+1*Identified Regulation subscale score) + (–1*External Regulation subscale score) + (–2*Amotivation subscale).

According to [22], the Introjected Motivation subscale was not considered in computing the RAI.

The final RAI measure served as an indicator of a person's overall motivational orientation, with positive scores representing more autonomous regulation and negative scores representing more controlling regulation.

***Spielberger State/Trait Anxiety Inventory (Short Italian form)* [23]**

It consists of 10 items in two subscales. Five of these measure state anxiety (STAIS) (e.g., *I feel that difficulties are piling up so that I cannot overcome them*), and the other five items assess trait anxiety (STAIT) (e.g., *I feel confused*). Each item is rated on a 4-point scale (1: Not at all, 2: Somewhat, 2: Moderately so, 4: Very much so). Both subscales are assessed separately. A higher score indicates higher anxiety. Cronbach's alpha coefficients of STAI were .84 for STAIT and .88 for STAIS.

The COVID-19 Online Learning Scale

After the psychological assessment, all participants filled out an online questionnaire named COVID-19 Online Learning Scale (COLS-19), developed ad-hoc for the present study exploring the following variables:

Learning habits and strategies before/during the COVID-19 pandemic

These variables were assessed by asking participants to rate on a 5-point scale with anchors 1: Never and 5: Always, a series of learning habits and strategies measuring the grade in which students complete a task more effectively and efficiently in an academic setting. Exempla of learning habits were: having scheduled time for studying; having a fixed time for studying; studying solo; studying with colleagues; studying at home or university (e.g., bibliotheca); Exempla of learning strategies were: creating conceptual maps; using keywords; self-examination by carrying out exercises/questionnaires on topics studied or summary tests.

Academic achievement

The academic achievement was assessed by asking students to indicate their average exam scores.

Mental Health and Help Requests

Finally, the OL's impact on student mental health was measured by exploring to whom they ask for help.

Specifically, *mental health problems* were assessed with a direct question – i.e., Do you have Physical and Mental Health problems during the COVID-19 pandemic? Moreover, with a question in which participants might specify the physical and mental health problems such as organic and functional problems (e.g., gastro/intestinal problems, respiratory problems, headaches), anxiety, insomnia, mood alteration, inappetence, and asthenia they had during the COVID-19 pandemic.

As well, *help requests* were assessed, asking participants to indicate first if they ask for help or not (i.e., Do you ask someone for help during the COVID-19 pandemic?) and then to specify who (i.e., Whom you ask for help?) choosing from different categories of people such for instance partner, relatives, friends, psychologists, doctors, spiritual guide, or priests.

Procedure

Participants were recruited by adopting a snowballing procedure. The link to the survey was posted on the online classrooms of the researchers' university courses and social media of students' associations over twelve weeks during the COVID-19 s-wave Italian lockdown phase (March-May 2021).

All participants completed the survey during their online classrooms with an average of about 30 min. Data were collected automatically by MS Forms. According to the Declaration of Helsinki, all participants gave written consent about the anonymity of data handling and were not compensated financially or through additional university credits. The Bioethics Committee of the University of Palermo has approved the current study (n. 38/2021).

Data Analysis

This study was explorative and used a quantitative design with structured scales. Thus, firstly it was calculated descriptive statistics and Pearson's linear correlations were used to analyze the impact of psychological variables on OL activities. Then, participants were into two groups having HIGH vs. LOW scores in each of the psychological questionnaires (i.e., General Self-Efficacy Scale, Academic Motivation Scale, Spielberger State-Trait Anxiety Inventory) by the median value.

Finally, a series of factorial two $\times$ two repeated measures multivariate analysis of variance (RM-MANOVA) were performed on scores obtained by participants on the COLS-19 scale.

All data analyses applied the IBM SPSS 26.0 software package (IBM Corp. Released 2011, IBM SPSS Statistics for Macintosh, Version 20.0. Armonk, NY: IBM Corp).

3 Results

Table 2 reports Pearson's linear correlation among all the study variables.

On average, participants show high levels of general self-efficacy ($M = 28.02$, $SD = 4.55$); their orientation toward academic motivation is an autonomous regulation even if the levels are not so high ($M = 19.51$, $SD = 8.71$), and they present high levels of trait anxiety ($M = 12.87$, $SD = 3.62$).

As regards Pearson's linear correlations, results show a significant positive association between self-efficacy and academic motivation ($r = .26$). In contrast, a significant negative association between self-efficacy and trait anxiety ($r = -.34$) as well as between academic motivation and trait anxiety ($r = -.19$) was found.

Table 2. Pearson's correlations for Self-Efficacy, Academic Motivation, and Trait Anxiety (N = 1028)

	1	2	3
1. Self-Efficacy	-		
2. Academic motivation	.26**	-	
3. Trait Anxiety	−.34**	−.19**	-
M	28.02	19.51	12.87
SD	4.55	8.70	3.62
Skewness	−.026	−1.24	−.237
Kurtosis	.268	2.12	−.582

3.1 The Effect of OL on Learning Habits

A first factorial RM-MANOVA was performed on each item of the COLS-19 Learning habits subscale considering the HIGH/LOW scores for psychological measures (i.e., self-efficacy, academic motivation, and trait anxiety) as between-subjects factors and the BEFORE/AFTER the COVID-19 pandemic as a within-subjects factor.

Results show a significant main effect for the between-subject factor HIGH/LOW scores related to Self-Efficacy, F (7, 1020) = 8.85, $p < .001$, Academic Motivation, F (7, 1020) = 9.91, $p < .001$, and Anxiety, F (7, 1020) = 4.31, $p < .001$.

There was also a significant main effect for the within-subject factor BEFORE/AFTER for Self-Efficacy, F (7, 1020) = 99.8, $p < .001$), Academic Motivation, F (7, 1020) = 99.7, $p < .001$, and Anxiety F (7, 1020) = 5.38, $p < .001$.

However, a significant interaction HIGH/LOW scores x BEFORE/AFTER has emerged only for Motivation F (7, 1020) = 99.7, $p < .001$, and Anxiety, F (7, 1020) = 3.40, $p < .001$, but not for Self-Efficacy, F (7, 1020) = 1,27, *n.s.*

Table 3 shows the univariate interaction effects for each COLS-19 Learning Habits subscale item.

To this respect, it was found that during the OL activities due to the COVID-19 pandemic, individuals with lower scores on self-efficacy reduced the scheduled time for studying more than those with higher scores, F (1, 1026) = 4.64, $p = .03$.

Undergraduates with lower scores on the RAI index, having a controlling regulation for their academic motivation, decreased their time scheduling during their study activities in the switching before and during the COVID-19 pandemic, F (1, 1026) = 3.91, $p = .05$, and their learning habit of taking notes during the OL lectures, F (1, 1026) = 9.21, $p < .01$. As predictable, considering the pandemic social restriction measures, the habit of studying with colleagues also diminished in students with a controlling regulation for

Table 3. Univariate interaction effects at the RM-MANOVA for Self-Efficacy, Motivation, and Trait Anxiety on COLS-19 Learning Habits (N = 1028)

Items	Self-Efficacy			Motivation			Trait Anxiety		
	F	*p*	$\eta^2 p$	F	*p*	$\eta^2 p$	F	*p*	$\eta^2 p$
Scheduled study time	4.64	.03	.005	3.91	.05	.004	25.52	< .001	.026
Flexible study time	.284	.59	.000	.71	.40	.001	.41	.52	.000
Taking notes	2.77	.09	.003	9.21	.002	.009	16.44	< .001	.016
Studying solo	.17	.68	.000	.54	.46	.001	2.94	.09	.003
Studying with colleagues	.88	.35	.001	4.52	.03	.004	2.14	.14	.002
Studying at home	.91	.34	.001	1.19	.27	.001	5.96	.01	.006
Studying at university	1.89	.17	.002	.26	.61	.000	4.57	.03	.004

their academic motivation more than those with a more autonomous one, F (1, 1026) = 4.52, $p = .03$.

With concerns to trait anxiety, results show that students with higher levels of trait anxiety display reduced learning habits in scheduling time for studying, F (1, 1026) = 25.52, $p < .001$, taking notes during OL lectures, F (1, 1026) = 16.44, $p < .001$, and contrarily increased their habits to studying both at home, F (1, 1026) = 5.96, $p = .01$, and at university, F (1, 1026) = 4.57, $p = .03$, more than their colleagues with lower anxiety levels.

3.2 The Effect of OL on Learning Strategies

A second factorial RM-MANOVA was performed considering the HIGH/LOW scores for psychological measures (i.e., self-efficacy, academic motivation, and trait anxiety) as between-subjects factors and the answers to the COLS-19 Learning strategies subscale as the within-subjects factor.

RM-MANOVAs display a significant main effect for the between-subject factor HIGH/LOW scores related to Self-Efficacy, F (12, 1015) = 7.44, $p < .001$, and Academic Motivation, F (12, 1015) = 11.35, $p < .001$.

There was also a significant main effect for the within-subject factor BEFORE/AFTER Anxiety F (12, 1015) = 8.88, $p < .001$.

Moreover, a significant interaction BEFORE/AFTER x HIGH/LOW scores has emerged for all studied variables, Self-Efficacy, F (12, 1015) = 3.31, $p < .001$, Motivation, F (12, 1015) = 2.09, $p = .01$, and Anxiety, F (12, 1015) = 3.49, $p < .001$. Table 4

Table 4. Univariate interaction effects at the RM-MANOVA for Self-Efficacy, Motivation, and Trait Anxiety at COLS-19 Learning Strategies

Items	Self-Efficacy			Motivation			Trait Anxiety		
	F	p	η^2p	F	p	η^2p	F	p	η^2p
Summarize	9.10	.003	.009	.01	.90	.000	5.15	.02	.005
Create conceptual maps	14.79	$<$ .001	.014	.66	.42	.001	1.84	.17	.002
Highlight crucial argument	4.16	.04	.004	3.22	.07	.003	1.77	.18	.002
Identify keywords	2.81	.09	.003	2.77	.09	.003	3.17	.07	.003
Re-reading an argument	.07	.78	.000	.61	.44	.001	7.53	.01	.007
Use a studying timetable	.06	.79	.000	4.85	.03	.005	5.55	.02	.005
Self-reflection on the content through questions	.18	.67	.000	4.36	.04	.004	.98	.32	.001
Intersperse different subjects in the same study session	8.87	.003	.009	7.53	.01	.007	20.31	$<$ .001	.019
Self-examination by carrying out exercises or tests	7.96	.005	.008	8.85	.003	.009	1.38	.24	.001
Giving explanations or formulating hypotheses on the causes of the studied phenomena	11.67	.001	.011	12.06	.001	.012	11.65	.001	.011
Creating mental images of the studied content	2.95	.08	.003	12.11	.001	.012	10.41	.001	.010
Verbal repetition	1.31	.25	.001	.28	.59	.000	12.51	$<$ .001	.012

shows the univariate interaction effects for each COLS-19 Learning Strategies subscale item.

Findings show that during the OL activities due to the COVID-19 pandemic, students with lower scores on self-efficacy significantly reduced the strategy of summarizing, F (1, 1026) = 9.10, p = .003) and o, F (1, 1026) = 8.87, p = .003. *Vice versa*, university students with higher levels of self-efficacy significantly increased the use of learning strategies such as creating conceptual maps, F (1, 1026) = 14.79, $p < .001$, becoming able to use self-examinations by carrying out exercises, F (1, 1026) = 7.96, p = .005 and to apply the strategy of explaining the causes of studied phenomena, F (1, 1026) = 11.67, p = .001. The two groups' results about highlighting important arguments are not well defined even if a moderately significant interaction effect has emerged, F (1, 1026) = 4.16, p = .04.

Results display that university students with high academic motivation or having an autonomous regulation increased study strategies, as studying following a timetable, F (1, 1026) = 4.85, p = .03, using self-reflection on the content just studied through questions formulated by oneself or proposed by the book, F (1, 1026) = 4.36, p = .04, using self-examination by carrying out exercises or questionnaires on the studied topics, F (1, 1026) = 8.85, p = .003, giving explanations on the causes of the studied phenomena, F (1, 1026) = 12.06, p = .001, and creating mental images of the studied content, F (1, 1026) = 12.11, p = .001. In contrast, students with low RAI scores of controlling regulation in their academic motivation reduced the strategy of interspersing different subjects in the same study session, F (1, 1026) = 7.53, p = .01.

Data also showed that during the OL classrooms, people with high trait anxiety decreased the use of learning strategies such as summarizing, F (1, 1026) = 3.3, $p <$ .05, to space out the different subjects in the same study session, F (1, 1026) = 20.31, $p <$ .001, and to give explanations of formulating hypotheses on the causes of studied phenomena, F (1, 1026) = 11.65, p = .001.

On the contrary, students with low trait anxiety increased learning strategies as re-reading time and argument, F (1, 1026) = 7.53, p = .01, studying following a fixed timetable, F (1, 1026) = 5.55, p = .02, creating mental images of the studied contents, F (1, 1026) = 10.41, p = .001, and repeating verbally, F (1, 1026) = 12.51, $p <$ .001.

3.3 The Effect of OL on Academic Achievement

A univariate ANOVA was performed considering the HIGH/ LOW scores for psychological measures (i.e., self-efficacy, academic motivation, and trait anxiety) on academic achievement scores.

Results display that Self-Efficacy, F (1, 978) = 10.03, p = .002, Academic Motivation, F (1, 978) = 23.77, $p <$ .001, and Trait Anxiety, F (1, 978) = 8.47, p = .004, have a significant effect on academic achievement in university students (Table 5).

Table 5. Univariate ANOVA for Self-Efficacy, Motivation and Trait Anxiety on academic achievement

	F	***p***	$\eta^2 p$
Self-Efficacy	10.04	.002	.010
Academic Motivation	23.78	.000	.024
Trait Anxiety	8.47	.004	.009

3.4 The Effect of OL on Academic Achievement

Finally, results on the OL's impact on students' physical and mental health display a consistent prevalence of students reporting mental health problems (64%) in a spectrum of organic and/or mental diseases (see Table 6).

Moreover, more than half of the sample (61.3%) affirmed that they requested help, especially from partners (19.7%), friends (14.9%), relatives (13.1%), health professionals like psychologists or medical doctors (9.7%), and spiritual directors (0.4%).

Table 6. Percentage of physical and mental health problems for all participants (N = 1060)

	%
Organic diseases	16.0
Anxiety	46.1
Insomnia	35.0
Altered mood	43.5
Inappetence	8.3
Asthenia	4.7
Other problems	9.4
No health problems	36.0

4 Conclusion and Discussion

The present study, in line with literature underscoring the impact of stress appraisals on the mental health of students navigating the COVID-19 pandemic [24], shows a strong interrelation between psychological variables such as self-efficacy, academic motivation and trait anxiety, and the OL activities during the COVID-19 pandemic.

Indeed, self-efficacy was crucial for managing more learning strategies than habits. For example, the OL activities impact scheduling time for studying and managing cognitive learning strategies helpful in acquiring study materials, such as summarizing or elaborating and combining different subjects during the same study session for students low on self-efficacy. A similar trend has also emerged for students with a controlling regulation, more characterized by extrinsic academic motivation, and with a high level of trait anxiety.

Furthermore, the results of the current study evidenced that university students increased their physical and mental health problems during the switching between traditional and OL classrooms due to the COVID-19 pandemic. Such results are coherent with studies demonstrating that the COVID-19 pandemic has a significant psychological impact. For instance, the result of the incapacity of college students with low self-efficacy skills, less autonomous in pursuing learning goals, and very anxious to actively regulate fixed time scheduling for study activities could be interpreted in the light of a recent study demonstrating how the lockdown state imposed by the COVID-19 has significantly changed people's rhythms of life. According to [25], the loosing of daily official timing routines during the lockdown impacted the perceived control of the time that, in turn, has a mediator effect on time management behaviors on the self-reported job or academic performance [26]. This altered subjective perception of time control could be responsible for higher psychological distress and mental health issues [27].

Thus, psychologists and educators might deliver autonomy-supportive programs that teach students to cope with anxiety from attending OL classes. Previous studies [28, 29] on the psychological and emotional impact of the COVID-19 pandemic reported higher anxiety levels in university students. They highlighted the need for support mechanisms that education institutions should establish to guarantee students' well-being and help them cope with psycho-emotional factors linked to global crises [30].

Moreover, educators might also help students to reach better academic outcomes using OL since it provides a more flexible, self-paced, and informal learning environment for students [31]. In any crisis, there is also an opportunity. The use of technology and digital devices highlighted some advantages that are likely to be considered for the future of education, particularly those related to the benefits of educational technology [30].

The increasing of mobile technologies represents an excellent way to access the learning process [32], which can revolutionize education by combining mobile and game-based learning approaches [33]. An example is Mobile Game-based Learning, which combines learning with playing, providing an environment where students can learn using gaming through smartphones. Previous studies on using Mobile Game-based Learning highlight improvement in students' motivation and academic outcomes.

Results of the present study need to consider some limitations: 1) the cross-sectional design applied in this work does not allow us to make cause-and-effect inferences. Thus, future research could replicate the study with other methodologies, such as longitudinal studies, to monitor better the learning strategies applied by undergraduates; 2) the convenience sample, even if it plays a valuable role in social science research [22], is not balanced by gender; still, it is hoped to replicate the work by balancing the male-female ratio; 3) a non-random population sample was applied. Thus, generalization cannot be made to the entire population of university students; so future cross-cultural studies on more representative samples from different universities are needed to corroborate this study's results.

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Machine-Learning-Based Software to Group Heterogeneous Students for Online Peer Assessment Activities

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Abstract. Since the academic year 2017/2018, a peer assessment activity was included in the online Genomics laboratory for the master's degree course in Biological Sciences of the University of Camerino, with the aim of improving learning outcomes and soft skills in students, such as team building and critical thinking. Creating groups in university courses is not easy because of the large number of students, that leads teachers to realize groups totally randomly, a procedure that is not always effective. One of the factors that influences the success of collaborative learning is the creation of heterogeneous groups based on the students' behaviors. Despite little improvements, the online genomics laboratory highlighted some gaps. Random groups didn't ensure that each group was composed of heterogeneous students, and it leads some students to have a bad perception of the peer review activity, negatively affecting their engagement and motivation. This work proposes a new Machine Learning Approach and the realization of a specific software, able to create effective heterogeneous groups to be involved in the online peer assessment process, in order to improve learning outcomes and satisfaction in the students. The aim is to check the improvement of the peer assessment effectiveness using heterogeneous groups compared to random groups of students. Two editions of the online laboratory of Genomics were analysed, examining the students' results and perceptions to verify the impact of the Machine Learning approach designed in this work.

Keywords: On-line Peer Assessment · Working group · Machine learning

1 Introduction

Universities promote innovative teaching that allows an improvement of learning in terms of knowledge and soft skills, including the student as an active actor in the training process.

Collaborative activities such as peer assessment are effective teaching methodologies since they improve learning outcomes by promoting active learning [1]. They also develop the students' social skills such as decision making, communication, collaborative and critical thinking [2, 3].

Peer assessment is a collaborative learning technique based on a critical analysis by learners of a task or artefact previously undertaken by peers [4]. In the peer assessment

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process, students reciprocally express a critical judgment about the way their peers performed a task assigned by the teacher and give a grade to it. Furthermore, students provide their peers with detailed qualitative feedback to guide and help them in the constructive revision of their work for the teacher evaluation.

To produce the feedback, the students use a rubric [5], which is a schema of the criteria for assigning marks for each step of the task. The rubric is usually prepared by the teacher in collaboration with the students themselves, thus promoting metacognitive reflection on the quality of the task or artefact to be produced.

The literature shows how peer assessment supports and improves learning, both for the students who receive the feedback and those who give it, because the activity triggers self-assessment and critical reasoning with a focus on the tasks produced by both [6].

Since the academic year 2017/2018, a collaborative activity of peer assessment, used as an evaluation process with a training function, was included in the online laboratory of Genomics for the master's degree course in Biological Sciences of the University of Camerino (Italy), thanks to the use of digital technologies. This experimental procedure was entirely conducted online, using the University's Moodle e-learning platform. Analysing the students' perceptions related to this collaborative activity carried out in all the past editions, some critical issues emerged on the composition of the reviewers' groups, selected randomly.

Groups were entirely created by a Moodle plugin which automatically and randomly provided the distribution of users in different groups, based on the teacher's preferences (number of groups and users for each group). Due to the random selection, the teacher did not pay attention to including students of different levels of knowledge and abilities into the groups. This unbalanced distribution of students led to creating groups with excellent students and groups with students showing difficulties in the study.

Despite little improvements of learning outcomes in the collaborative activities based on random groups, this teaching method highlighted some gaps:

1. Random groups didn't ensure that each group was composed of heterogeneous students.
2. Because of random groups, some students have a bad perception of the peer review activity, negatively affecting their engagement and motivation. [7]

Ensuring the heterogeneity of the students in terms of cognitive resources (based on the tests results achieved during the course path and interactions with other peers), characteristics (gender and provenience) and behaviours (how they used the tools in the e-learning platform) is essential for maximizing success in group works [8].

In university courses, forming optimal heterogeneous groups of students for collaborative activities is not always an easy task. Usually, different approaches don't always guarantee the formation of heterogeneous groups, such as random selection, automatic selection, and teacher selection [9]. The last approach could guarantee the realization of heterogeneous groups. It consists in the selection of students, by the teacher, based on pre-established characteristics, such as knowledge, skills, interests and learning style [10]. However, for the university teachers, the identification of different profiles of students who attend the classroom, influenced by certain characteristics and behaviours, is complicated, not only for the high number of participants, but also for the relatively short duration of the courses that do not always require a mandatory attendance. Different works show how the use of models help teachers to define students' behaviours related to their learning process [11].

Some Machine Learning algorithms, such as Clustering, reveal their usefulness for their ability to group similar student's types through specific behavioural indicators such as "presence coefficient", "study coefficient", and "activity coefficient" [12]. The weakness in the online learning environments is the lack of a specific software that easily allows the creation of these groups automatically, facilitating the teacher's work.

For this purpose, a computer-based application was created to allow the artificial-intelligent creation of heterogeneous groups, using unsupervised Machine Learning techniques [13] applied to the Learning Analytics produced by the students during their attendance of an online course in the Moodle platform [14]. The software firstly defines different clusters of students (each cluster includes students with similar behaviours in the online path) and then heterogeneous groups (each group includes students belonging to different clusters). For the first scope, K-means clustering algorithm was chosen for its effectiveness in grouping students based on online behaviour in e-learning courses [15]. Alternatively, the realization of heterogeneous groups required an algorithm specifically developed, that includes in each group at least one student belonging to a different cluster, ensuring heterogeneity. This software application was implemented in the academic year 2020/2021 in the Genomics online laboratory (composed by international students from: Africa, India, China, and Italy), in order to automatically create heterogeneous groups of students for the collaborative activity of the peer assessment.

The aim of this work is to check the improvement of the effectiveness of the peer assessment activities using heterogeneous groups (created by the software developed), compared to random groups, answering to the following questions:

1. Does peer assessment based on heterogeneous groups enhance the improvement of students' performance compared to the same activity based on random groups?
2. Does the use of the heterogeneous groups influence an improvement in students' perceptions compared to the same activity that required random groups?

A uniform and substantial improvement both for the students' works (after the quantitative/qualitative feedbacks given by the peers) and for the students' perceptions (related the quality of the feedback received) was obtained in the Genomics laboratory edition 2020/2021 that used the intelligent software, described in this work, for the creation of heterogeneous groups of students.

2 Methodology

2.1 Description of the Activities

The on-line Genomics laboratory is supplementary to the classroom learning. It allows students to perform genetic sequence analyses starting from real experimental data. The course consists firstly of teaching materials (as video tutorial, slides, pdf documents, video experiments) to be attended in self-learning, and then a second part characterized by a collaborative activity that require working groups. A specific gene-sequence case study, that contains one gene represented by exons and introns, is delivered to students belonging to the same group. After the self-study of teaching materials, each student has to perform individually the analysis of the sequence performing a task that requires the submission of an essay characterized by questions related to the gene-sequence case assigned.

In the first part students had to work individually and only in the second part they have to interact with the other students of the same group, during the collaborative activities. Once concluded the elaboration of the task, each student had to upload their final report using the Workshop module of the Moodle platform to start the on-line peer assessment. This activity promotes mutual assistance among the students with different levels in competence and knowledge and in addition develops soft skills, such as critical thinking, sense of responsibility and time scheduling. In this activity each student performed two peer assessments to colleagues' reports and, after considering feedback received, can decide if edit or not his task (Fig. 1).

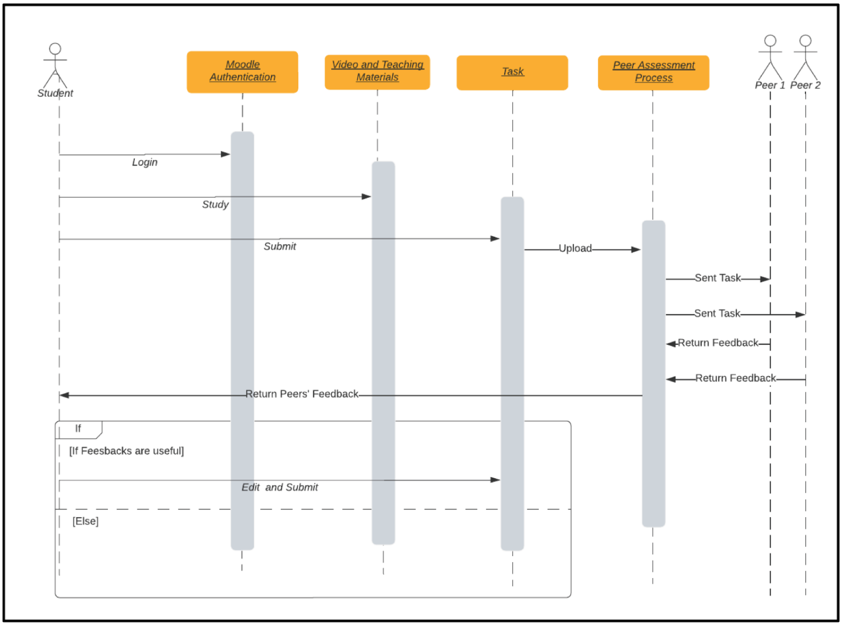

Fig. 1. Sequence diagram of the flow of the peer assessment activity.

Each student during the evaluation phase filled a rubric, already tested in past editions of the Genomics Laboratory course [7], writing quantitative and qualitative judgements related to the task processed. The rubric consists in a set of clear criteria used to help teachers and students to focus on what is valued in a subject, topic, or activity [16]. For the quantitative judgement, students must evaluate the task of the peer giving a score, with a maximum value of 30. For the qualitative evaluation feedback with tips was required that could help peers in improving their tasks, before the last submission, that will be assessed by the teacher.

2.2 Participants

In the past edition of the on-line Genomics Laboratory 41 students (23 females and 18 males), composed of Italian, Chinese, African and Arabian people, participated in the course. 8 Groups of 5–6 people were created totally randomly.

The participants of the new edition of the on-line course were 41, characterized by 26 females and 15 males. Students came from all over the world, such as Italia, Netherland, Albania, Africa, Arabia, and China and through the Machine Learning software aimed to the creation of heterogeneous groups, they were sorted in 8 groups, 7 composed by 5 people and 1 group by 6 people.

The participation was voluntary, and students actively participated in the on-line activities. At the end of the laboratory an extra-point was added to the final score of the Genomics exam for students that completed the course-path, including the submission of the task and the realization of peer review.

2.3 Machine Learning Approach

Teachers involved in totally on-line courses can find difficulty profiling student behaviour to create successful heterogeneous workgroups for collaborative activities, based only on monitoring students' Moodle Log data.

For this reason, in the past editions of the on-line Genomics Laboratory course, the creation of groups was totally random, and not always effective for the peer assessment processes because it didn't ensure the heterogeneity in each group.

In the last edition of the on-line course, a Machine Learning approach was performed to create heterogeneous groups of students, with the aim of improving the learning outcomes in students involved in collaborative activities. The software, already tested, consisted in the execution of the K-Means unsupervised techniques to predict different clusters of students' profiles (based on behaviour in the platform) and in the realization of heterogeneous groups selecting at least one student from each cluster [14].

The dataset was characterized by the selection of the learning analytics, extracted by the reports of Moodle, that allowed the detection of various features of the student learning process, such as the "presence", "study" and "activity-interaction" [12]. These features permit the finding of student behaviour through clustering.

Specifically, the following data were selected: number of logins, last login, total time online, number of video tutorials, clicks for video tutorials seen, number of video experiments seen, clicks for video experiments seen, number of pdfs downloaded, number of exercises performed.

After the creation of the clusters, the software performs the algorithm that automatically and uniformly divides the students of various clusters in different heterogeneous groups (Fig. 2).

It first determines the number of groups to create, calculating the number of students to be included in the group, and then, it distributes group members equally assigning one or more students from each cluster (considering the lengths of each cluster) to each

$$student\_for\_het\_group = \frac{cluster\_lenght}{nr\_het\_groups}$$

Fig. 2. Number of the students belonged to the same cluster to be included in each heterogeneous group.

group, ensuring heterogeneity within. At the end of this step the list of the groups is displayed to the teacher.

2.4 Data Collection and Methodology

The results obtained from the quantitative analysis of the peer assessment process, on two different editions of the Genomics online laboratory, (2017/2018, using random groups; 2020/2021, using heterogeneous groups realized by the intelligent software), were compared to reply to research questions. It was chosen these two specific editions, because they included the same activities in the on-line course and the same number of the students involved, also in terms of international students.

In detail we analysed:

1. the improvements of the grade related to the works produced by the students after the peer assessment process (we compared the grades given by the teacher before and after peer assessment process);
2. the questionnaire on the perception of the students regarding the collaborative activity of the peer assessment.

Firstly, the score got by the students related to the task submitted before the peer assessment, was compared with the score of the final version of the task uploaded following the peers' feedback. The aim was to see the different impact in the improvement of learning outcomes in both editions respectively using random group approach (edition 2017/2018) and heterogeneous groups approach through Machine learning application (edition 2020/2021).

Then a final questionnaire based on similar already tested investigations related to the users' satisfaction about collaborative activities [17] was delivered anonymously at the end of the peer assessment. It was characterized by 21 questions ranked on a five-point Likert scale and 10 open ended questions, covering 5 main topics such as:

1. general opinion on peer assessment activity,
2. improve the final report before the submitting of the final draft,
3. improve critical thinking,
4. self-evaluation,
5. enhance the learning of the main concepts in Genomics.

The same questionnaire was delivered in both editions, to quantify the impact of the new machine learning compared to the previous approach not only in terms of performance but also in terms of perception.

2.5 Data Analysis

The results of the research questions required some analysis that involved the comparison of the grades obtained by the students before and after the peer assessment process and the answers of the questionnaire related the perception of the students and their behaviour about the peer assessment.

The comparison between the grades was performed through the "t-test paired two sample for means" of MS Excel, a statistical method used to compare the means of two groups [18]. The T-test was applied to analyse the means of the grades obtained by the students before and after the peer assessment for each edition of the on-line courses. The goal was to discover if the p values in the both editions returned a significant difference between the grade obtained before and after the review process, and then comparing the means in the two on-line courses to detect if there were some differences in terms of effectiveness.

The analysis of the questionnaire was made using the software Excel, selecting the questions that define satisfaction and perception related to the peer assessment process, also in terms of improvement of soft skills and knowledge. In particular the questions ranked on a five point Likert scale were used for the analysis in order to compare the percentage of satisfaction between the two editions and if they register important differences.

3 Results

The results required an analysis of the students' behaviour, grades and perceptions, in order to satisfy the research questions:

1. Does peer assessment based on heterogeneous groups enhance the improvement of students' performance compared to the same activity based on random groups?
2. Does the use of the heterogeneous groups influence an improvement in students' perceptions compared to the same activity that required random groups?

3.1 Realization of Heterogeneous Group

Firstly, a dataset was created in order to execute the software (that include clustering techniques and the sorting algorithm) aimed at the creation of effective heterogeneous groups.

Different features were extracted by Moodle logs and organized in the dataset, selecting the data that better characterized the students' behaviour in the platform, based on their interaction in the on-line course during the first period of individual study. These features were included in the dataset:

1. login frequency;
2. total time online;
3. number of views of video experiments online;
4. frequency of viewing of video experiments online;

5. number of views of teaching materials;
6. frequency of viewing of teaching materials;
7. number of exercises performed.

The dataset was then processed by the K-means clustering algorithm, implemented in the software.

K-means is an unsupervised machine learning algorithm that attempts to partition the dataset into K predefined distinct and non-overlapping subgroups (clusters) [19].

Since this algorithm needs the number of clusters to be created as input, the elbow method was used to find the optimal number of clusters [20].

K-means returned 3 clusters of students (identified by ID). Students were then included automatically by the sorting algorithm in 8 heterogeneous groups, including in each group at list one member belonged to a different cluster.

These are the clusters returned:

1. Cluster 0: [0, 14, 16, 25, 26, 28, 32, 40];
2. Cluster 1: [2, 6, 9, 11, 12, 15, 17, 18, 20, 24, 29, 35];
3. Cluster 2: [1, 3, 4, 5, 7, 8, 10, 13, 19, 21, 22, 23, 27, 30, 31, 33, 34, 36, 37, 38, 39].

Based on the clusters obtained, the software creates 8 heterogeneous groups, paying attention to try to ensure the heterogeneity in each group:

1. Group 0 [0, 2, 1, 3, 4];
2. Group 1 [14, 6, 5, 7, 8];
3. Group 2 [16, 9, 10, 13, 19];
4. Group 3 [25, 11, 21, 22, 23];
5. Group 4 [26, 12, 27, 30, 31];
6. Group 5 [28, 15, 33, 34, 36];
7. Group 6 [32, 17, 37, 38, 39];
8. Group 7 [40, 18, 20, 24, 29, 35].

3.2 Results of Peer Assessment

Once created the groups, and after the first submission of the task at the end of the self-learning part, students were included in the peer assessment process.

In particular, two reports, written by peers belonging to the same group, were assigned to each student, who had to provide a total score (sum of the values assigned to each grid's criteria) and to write general feedback related to the reports aiming at improving the quality of the works.

At the end of the process the teacher assigned to each student two grades related to the task submitted, respectively to assess the task before and after the peer assessment. For each student a comparison between the scores obtained was made to check the effectiveness of the peer review process.

Does peer assessment based on heterogeneous groups enhance the improvement of students' performance compared to the same activity based on random groups?

A new analysis was made to answer this research question, comparing the differences between the score obtained by students before and after the peer assessment process for the edition 2017/2018 and 2020/2021, determining if there were differences between them, and checking if the heterogeneous groups approach, based on Machine Learning, enhance the improvement performance compared to the random group approach.

Before defining the correct tool to use for the statistical analysis, the normality of the data was assessed using the Shapiro Wilk Test with R [21]. In all cases of the both editions of the course, the Shapiro Wilk test returned a not-significant p-value, (greater than the alpha value of 0, 05). Because of the normal distribution of the grades, the paired t-test was selected for the comparison (the same elements were evaluated in different times, before and after the peer assessment). T-test returned p-values lower than the level of significance (alpha level) of 0, 05 for both comparisons. These data confirmed a statistically significant difference between the pre-treatment condition and the post-treatment condition; the post-treatment average was higher in both years, therefore this difference is attributable to the efficacy of the peer assessment process (post treatment was higher than pre-treatment). Considering that the edition based on heterogeneous group with an increase of the grade (1, 41) was greater than the edition based on random group (0, 67), it can be assumed that the peer assessment process related to the new edition of the course statistically performs better than the previous edition (heterogeneous group edition p-value 0.0000000027 vs random group edition p-value 0.0000637). The Fig. 3 represents the grades obtained by students of the Genomics Laboratory 2017/2018, while the Fig. 4 the grades of students involved in the Genomics Laboratory 2020/2021. The figure shows an improvement of the performance after the collaborative activity in both the editions, even if the gaps between the grades obtained by the students involved in the peer assessment with heterogeneous groups are more evident compared with the other approach.

This trend is also confirmed by the results returned by the data analysis because the heterogeneous group approach returns the 41% of students that achieved a grade with an increment $> \ = 2$ and only 20% of students that didn't improve their grade, compared to the random group approach where only 7,5% of the students achieved a grade with an increment $> \ = 2$ and instead the 42,5% of students didn't improve their grade after the peer assessment. It's necessary to specify that, as the histogram in Fig. 4 shows, four people already achieved the maximum score before the peer assessment, and this fact means that the percentage of students who didn't improve their grade could be lower.

Does the use of the heterogeneous groups influence an improvement in students' perceptions compared to the same activity that required random groups?

Table 1 and Table 2 summarize the answers to the questions related to the peer assessment, selected by the questionnaires filled by students that participate in both editions of Genomics Course, in order to determine if the realization of groups of students using Machine Learning techniques gave benefits to students, affecting their satisfaction in the study. Analysing the answers released by students in the two surveys, the edition 2020/2021 returned very good results that reflect an improvement in terms of satisfaction compare to the other edition, as reported by the following results related to the answer of students involved in heterogeneous groups, realized by the application of Machine Learning: 83% agree (A) or strongly agreed (SA) in the use of the feedback to revise

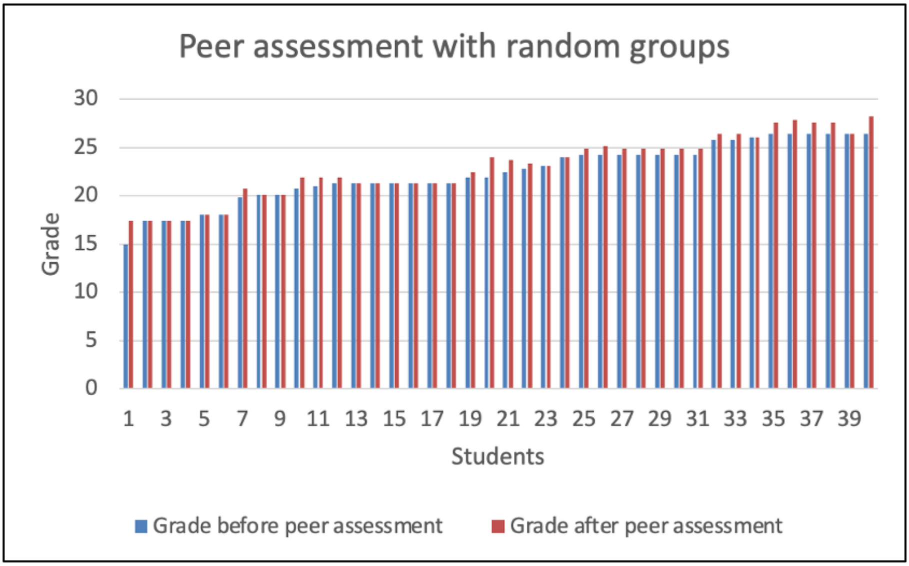

Fig. 3. Comparison between the grade obtained by students before and after the peer assessment with Random Groups.

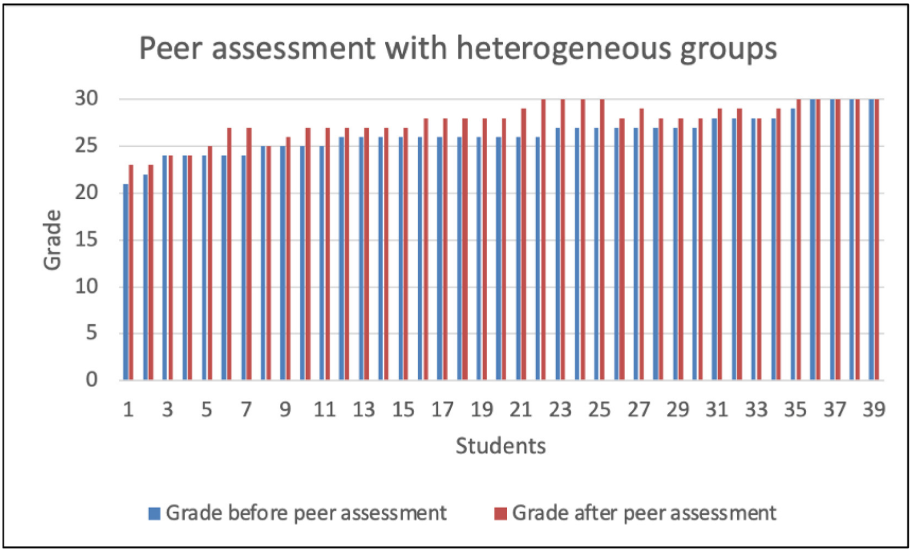

Fig. 4. Comparison between the grade obtained by students before and after the peer assessment with Heterogeneous Groups.

their tasks, 72% (A + SA) believe that peers are qualified to provide qualitative feedback/comment about the exercises, 74% improved their knowledge on the course topic being an assessors and providing critical feedback, 74% (A + SA) think that the quality of the final work improved because of the peer-assessment process, and 91% (A + SA) think that the peer-assessment process was a valuable learning experience.

Table 1. Results of the 5 questions selected by the questionnaire related to the on-line Genomics Laboratory 2017/2018, characterized by peer assessment based on random groups. SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree.

Questions	SD	D	N	A	SA
I used feedback/comments provided by peers to revise the first draft of my task	1%	21%	24%	47%	7%
I believe my peers are qualified to provide qualitative feedback about my exercises	4%	21%	39%	35%	1%
My understanding and knowledge of the topic improved by being an assessor and providing feedback	0%	7%	26%	54%	13%
The quality of my final work improved because of the peer-assessment process	2%	20%	23%	40%	15%
I think that the peer-assessment process was a valuable learning experience	2%	7%	10%	50%	31%

Table 2. Results of the 5 questions selected by the questionnaire related to the on-line Genomics Laboratory 2020/2021, characterized by peer assessment based on heterogeneous groups. SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree.

Questions	SD	D	N	A	SA
I used feedback/comments provided by peers to revise the first draft of my task	0%	0%	17%	49%	34%
I believe my peers are qualified to provide qualitative feedback about my exercises	1%	1%	23%	66%	6%
My knowledge of the topic improved by being an assessor and providing feedback	0%	3%	23%	54%	20%
The quality of my final work improved because of the peer-assessment process	0%	5%	20%	54%	20%
I think that the peer-assessment process was a valuable learning experience	0%	0%	9%	54%	37%

The perception of the students, that included very low percentage of the strongly disagree and disagree responses (at maximum 5%), confirmed the effectiveness of the artificial intelligence approach in the composition of the groups that provide benefits for the students for enhancing their learning experience.

4 Conclusions and Future Perspective

This work proposed a new Machine Learning Approach able to create effective heterogeneous groups of students to be involved in the online peer assessment process, in order to enhance learning outcomes and satisfaction in the students. The use of this tool overcomes the limitations of the standard Moodle activities, applying machine learning techniques by analysing the students' data extracted by the Moodle analytics.

The course "Genomics Laboratory " of the University of Camerino was delivered on-line in different academic years, where the peer-review activity was based on random groups, but it highlighted some gaps:

1. Random groups didn't ensure that each group was composed of heterogeneous students.
2. Because of random groups, some students could have a bad perception of the peer review activity, negatively affecting their engagement and motivation.

By exploiting the method here implemented, the use of heterogeneous groups helped the teacher in the creation of effective groups of students expected to work in the peer assessment process, increasing the probability to have a good review for each member of the group. In this way, each student was able to enhance its learning experience, performance, knowledge, and satisfaction, contributing to the achievement of high-quality learning outcomes.

Future development will consist of realizing new additional applications of the Machine Learning software used in this work, applying new functionalities that can improve the heterogeneity in each group and testing the software in a new on-line course in order to confirm its effectiveness.

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Analysis of MOOC Features in a Regional Platform: Design and Delivery of Courses

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Abstract. At least two motivations make relevant research on regional MOOC providers: (1) they are Learning at scale environments where a large amount of data is produced, the high number of learners can show different approaches to learning, the whole population can be analysed, teaching and instructional design methods can be compared; (2) regional platforms reach the interests and needs of population groups that have only sometimes registered in international platforms.

Therefore, we conducted a study at a large scale on EduOpen, an Italian MOOCs platform to which 28 institutions joined. The research aims to describe the current situation on EduOpen MOOCs, identify a latent model for the design and delivery of courses, and detect points of interest to enhance the platform's procedure. We used courses as statistical units and identified three groups of variables: basic features, design features, and delivery features. We used multiple correspondence analysis (MCA) with descriptive statistics to answer the research questions. MCA is a method for data reduction for qualitative variables in which the categories assumed by the variables play a central role in defining a smaller number of dimensions.

We found two dimensions that define the structure that underlies the design process – COURSE DENSITY and CONTENT ATTAINABILITY, and the delivery process – DIFFUSION and PARTICIPATION. Some focal points that EduOpen members can consider improving strategies in the design of the courses are related to the organization of activities and content, the scheduling of activities and whole courses, the levels of interaction in the courses, and the definition of qualified professional figures for design and tutoring.

Keywords: Learning@Scale · Multiple Correspondence Analysis · EduOpen

1 Introduction

Numerous regional and global providers offer MOOCs (Massive Open Online Courses) all around the world. They differ in the number of registered learners, number and kinds of courses, language, business models, levels of openness, and so on [1].

At least two considerations have to be made on this globally diffused practice.

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1. *MOOCs platforms are an example of Learning at scale (L@S) environments where teachers deliver the sequence of learning activities. L@S environments offer opportunities and challenges in data-driven research, teaching and instructional design methods.*

In global and national contexts, Learning at scale (L@S) environments host courses and resources realized by a few experts/tutors for a huge number of learners.

In these environments, the focus goes indeed to *learners*, that are *at scale* for their numerosity and the diversity of experiences, goals, opinions among them. At the same time, we can assign the attribute "at scale" also to *research and data*, *adaptation* (meant as mass personalization), *time and space* (to learn anywhere and anytime), *pedagogy* (as new opportunities to enhance educational experiences in the digital age) [2].

In particular, the research on these environments used data to answer educational questions. Even if it perhaps did not conduct the hoped disruption in education [3], it can provide pieces of evidence in studies on educational policies, students' behaviours, and social phenomena. In fact, interdisciplinary studies about course design conducted with experimental approaches on more learning platforms contribute to using educational data to offer new directions in learning science.

The collected data in L@S environments refer to the whole population and not only to a sample; the big dimensions of platforms allow comparisons among instructional design and teaching methods with explanatory, predictive, and normative purposes. Interpretation of the meaning of variables and results, generalization of results to a wide population, and confidence in statistical tests affect the validity of the studies and make us risk of obtaining ambiguous results [4].

Two elements are fundamental for better efficacy of the studies, according to [3]: (1) researchers have to propose studies that test theory and practices in learning, introducing different kinds of instructional design, and use granularity of data to plan instructional designs functional to reach better learning outcomes; (2) they have to design and choose measurement tools and indicators to conduct the studies effectively.

2. *Global and regional platforms reach different goals in the diffusion of open education.*

Recent multi-platforms studies [5–7] underline that different learners register into global and regional non-English platforms. Regional platforms can receive and reply to the interests and training needs of a limited population (if compared to large providers) that, in some cases, could look at national platforms as the only way to participate in the training because of the language, the participation of well-known national universities, or the cultural background of the lecturers, teaching methods and course design [6].

For example, comparing Arab students registered on EdX and Edraak – a Jordanian platform – in [5], authors show that younger, female, and less educated students have registered in Edraak. They also confirm, for example, that the completion rate for similar courses on the two platforms can vary (three times higher in the Edraak), probably for the higher level of participation or, it cannot be excluded, for the levels of difficulty of the courses. These elements of diversity could signal that regional platforms, better than global ones, can use MOOCs as instruments for sharing and democratizing knowledge and training thanks to the role that language and culture can play in the collaboration and achievement of educational goals.

Starting from these two considerations, we propose an analysis on EduOpen, one of the small European regional Moodle-based platforms [1] for MOOCs delivery. Since 2016, about 400 courses were published on EduOpen (approximately one-third of all those produced in the Italian academic context), attended by more than 120 thousand who acquired about 90,000 attendance certificates.

This platform is part of the Italian MOOCs ecosystem that, according to Italian studies on open education [8], seems to be dynamic. In fact, about one thousand MOOCs was produced by 28 universities until 2021. Besides, Italian scenario in MOOC production appears more open for content licenses and accessibility mechanisms than similar countries, and fragmented, probably because of the lack of a national policy.

Nevertheless, EduOpen is the only network of universities and entities (28 at the moment) that offers MOOCs in a unique environment in Italy. Also for this reason, we defined this research as a *macro-level analytics* according to [9, 10]. Our analysis focuses on the strict relationship between research on MOOCs and Learning Analytics [11] and tries to identify a latent model for creating and delivering MOOCs in a cross-institutional context, EduOpen. Even if the analysis we present here is only realized on one platform, we considered it *macro* for the high number of universities/institutions involved and for the purpose of looking at the whole community and impacting the design and delivery processes of MOOCs. We didn't consider individual students' performances (*micro analytics*), groups of courses or individual institutions (*meso analytics*).

Applying a multivariate technique for data analysis, we try to reply to the following research questions:

- Q1. What dimensions can we identify in the design and delivery features of EduOpen MOOCs?
- Q2. Considering relevant events related to the platform updates in November 2018 and the Covid19 pandemic, did the course features change during the years?

The answers to Q1 e Q2 allow us to describe the current situation on EduOpen MOOCs, identify the latent elements in the course production and publication, and detect points of interest to enhance the platform's use.

The following sections describe the dataset and method used for the analysis (Sect. 2), the results (Sect. 3), and the conclusions (Sect. 4).

2 Method

2.1 Data

The research dataset comprised the total number of MOOCs published on EduOpen from 2016 to September 2022, which is equal to 418 courses.

We excluded 77 courses. In particular:

– 15 courses that stayed open for only a few weeks at the portal launch (2016) and didn't use all the rules defined by the coordination team and become the standard over the years;

- 12 courses published after June 2022;
- 39 courses called Capstone and used only for assessment in Pathway (groups of MOOCs that have a common educational goal);
- 10 courses called Courseware that are repositories of well-done teaching materials and not courses at all.

So, after the selection, the dataset consisted of 341 MOOCs.

2.2 Variables

We identified 13 variables retrieved from the design plans of the MOOCs (e.g., Course Categories, Starting Year, Training Hours, Language) and from the platform dashboard filled by logs and users' participation (e.g., number of Learners and Completion, number of Posts). Some of the variables considered, such as Number of Learners, were metric; we created ranges using quartiles to transform them into non-metric variables and apply multiple correspondence analysis (the method uses only qualitative variables). The variables in this procedure are Training hours, Activities/Hours, Duration, Number of Learners, and Completion Rate.

We divided variables into three groups: the first one collected Course categories and Starting year that represent the BASIC FEATURES of the courses; the second group detected the DESIGN FEATURES of the courses and comprised eight variables; the third one collected five variables related to DELIVERY FEATURES. The variables Duration and Editions were included in both the second and third groups because we believe that these elements influence the two phases of course realization. To clarify with an example: instructors can propose more than one edition of a course to take a tutored mode (Editions so can be considered a design feature) or because of good results in the participation in the first edition (Editions as a delivery feature).

A complete explanation of the variables is in Table 1. The first column contains the number of categories for each group of variables; the last one includes the percentage of courses belonging to each category.

2.3 Analysis Method

We used multiple correspondence analysis (MCA) with descriptive statistics to reply to the research questions.

MCA is a method for data reduction for non-metric variables in which the categories assumed by the variables play a central role in defining a smaller number of dimensions [12, 13]. This method has exploratory and descriptive purposes and aims to show the latent structure of a dataset through values and graphical representations (perceptual map) where the categories are plotted.

The distance of categories gives information on the relation among them. The proximity of the points in the perceptual map makes the similarity between categories visible. Points closer to the origin represent categories with frequencies more similar to the mean; points further away indicate modality values that deviate from the expected values. Quadrants and half-planes in the biplot can be considered in interpreting the distribution of points.

In this method, we can produce symmetric and asymmetric biplots that differ in how the distance among categories is calculated. In the former, the ones we used in our analysis, we can only compare categories of the same variable and make general comments on categories belonging to different variables.

The distance calculated between the frequencies of the categories leads to the calculation of an index called *inertia*. It represents the variance of the dimensions in which the variables are summarized; it also represents the distance of the categories from the axes in the visualization.

Other indexes are:

- `ctr` that denotes how much each category contributes to the dimension and so to the variability of the dataset.
- `cos2` that assumes values between 0 and 1 and is the representation quality level, i.e. how well the dimension represents the category.

We decided to use this method because we needed:

- to identify and describe a small number of elements (dimension) that can summarize the different features of a great number of courses;
- to include non-metric variables in the analysis that are particularly relevant in the design and delivery of the courses;
- to create visualizations that a large community of stakeholders could simply understand.

We used `R/RStudio` as analysis software and the packages: `factoextra` and `FactoMineR` to perform MCA [14].

3 Results and Discussion

About half of EduOpen MOOCs regard themes on Social Sciences (44.9%), mainly in sectors of Education, Economy, and Law. Arts and humanities (23.8%) is the following category. 87.4% of courses are delivered in Italian. The courses can be divided into two similar groups if we consider the delivery mode: tutored/self-paced. In Table 1, besides, we can observe that number of Posts/Participant is very low. These data suggest that interaction and collaboration processes are not beware in the design and delivery of the courses. 29.9% of courses are part of a pathway, and 57.7% are courses with multiple editions (the first or the following editions). Around 38.4% of courses have no closure data, so they can be considered "always open".

To identify dimensions in the design and delivery features of EduOpen MOOCs starting from course characteristics (Q1), we performed two MCA. We used the variables related to Basic and Design features in the first one; in the second one, we included variables of Basic and Delivery features.

As can be seen, the inertia value is around 20% in both analyses. Even if this value is quite low and more information could be retrieved by adding more dimensions, we decided to propose a solution with two dimensions to obtain a graphical visualization of the latent structure of data.

Table 1. Variables table.

Group	Variable	Categories	%
Basic features (13)	Course categories	Arts and humanities Computer & Data Science Health and Pharmacology Sciences Social Sciences Technology, Design and Engineering	23.8 10.3 4.7 12.3 44.9 4.1
	Starting Year	2016 2017 2018 2019 2020 2021 2022	14.1 16.1 22.6 20.5 11.4 7.9 7.3
Design features (21)	Training Hours	0–10 h 11–14 h 15–18 h 19–100 h	29.3 25.5 21.7 23.5
	Language	Italian English	87.4 12.6
	Mode	Tutored Selfpaced	50.2 49.9
	Pathway	Yes No	29.9 70.1
	Activities/Hour (ratio of the number of activities and the number of training hours)	0–2.9 3.0–3.7 3.8–5.1 5.2–22.8	27.0 23.8 24.3 24.9
	Duration (number of days the course was available)	0–100 days 101–150 days 151–257 days 258–1193 days Open (No closure data)	15.5 15.9 15.5 14.7 38.4
	Edition	Yes (Multiple edition) No (Single editions)	57.5 42.5
Delivery features (19)	Number of Learners	< 230 230–472 473–1142 > 1142	24.9 25.2 24.9 24.9

(*continued*)

Table 1. (*continued*)

Group	Variable	Categories	%
	Completion Rate	0–21% 22–29% 30–40% 41–72%	25.8 27.0 23.8 23.5
	Posts/Participant (ratio of the number of posts and the number of participant that completed course)	0.0 0.1 ≥ 0.2	44.0 31.4 24.6
	+ *Duration* and *Edition*		

Figure 1 is the biplot resulting from the first analysis. In the graph:

- Hard Science categories are in the top right sector, Social Sciences in the bottom right quadrant, Art and Humanities in the left. So, we can observe a clear division among categories;
- Self-pace (SP) and Tutored (T) are in the opposite sector near the origin. They didn't affect the dimensions related to the design;
- early Starting years (2016/2017/2018), long Duration, and high Training hours categories are on the right side of the figure;
- categories related to More editions and Pathway are in the bottom sectors;
- higher ratios Activities/Training hours are in the top sectors.

Dimension 1 (*inertia* = 11.2%) can represent COURSE DENSITY, which refers to the quantity and organization of teaching materials in the MOOC. Going from the left to the right, we can observe a change in the different types of workload: on the left, we have top categories of Activities/Hour and bottom categories for Hours; the contrary is on the right where, besides, we find also the category of courses that belong to pathways. This difference can be related to two periods: on the right between 2016–2018 and the left between 2019–2022.

Dimension 2 (*inertia* = 10.1%) can be seen as CONTENT ATTAINABILITY, that is, the possibility of reaching the content and the knowledge in training. On the bottom, we have "more attainable" categories related to the presence of more than one edition for a course and the organization of MOOCs in pathways where themes are set out more broadly; on the top, we have categories of Hard sciences and English that is more difficult for Italian learners that are the main participants on the platform. Besides, the categories related to the realization of one edition for a course or long-duration delivery that define courses that could be less updated or less findable in the platform among recent or featured courses are in the same sector.

According to `ctr` values, more involved variables are: Duration, Training hours, Pathway, Activities/Hour, Editions.

The sum of the inertia of the two dimensions is 21.3%. This means that these two dimensions explain the variance of the same percentage of the observations.

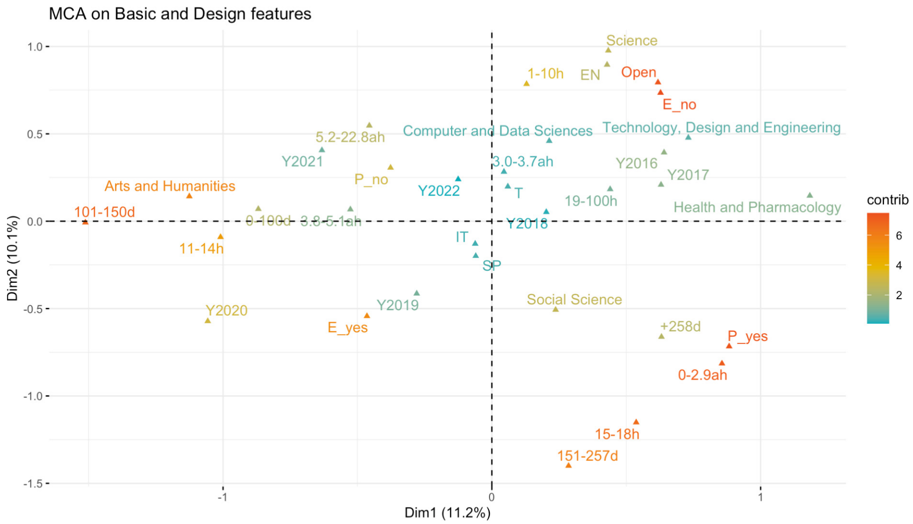

Fig. 1. Symmetric biplot of variables related to Basic and Design features of EduOpen MOOCs. Gradients show the contribution of each variable to the two dimensions (`ctr`).

In the second biplot (Fig. 2):

- Hard Science categories are distributed in the left sectors and more distant from each other than in the previous figure;
- the early Starting years (2016/2017/2018) are on the left side of the figure;
- the number of Learners enrolled in the course increases going from right to left;
- the number of Completion increases from the bottom to the top.

Dimension 1 (*inertia* $= 11.5\%$) can represent the different kinds of DIFFUSION of MOOCs seen in the two half-planes of the biplot. On the left side, we find categories of Starting years between 2016 and 2018, with a Duration of a long period, no other editions, a high number of Participants, and Hard Sciences. On the right half-plane, we find categories related to more recent years (Starting year), Course categories in Social Sciences and Arts and humanities, more editions, and a lower number of Participants.

Dimension 2 (*inertia* $= 7.8\%$) represents the level of PARTICIPATION in the courses. Going from the bottom to the top, the Completion rate, and the number of Posts per Participant increase.

According to `ctr` values, the variables involved are: Duration, Learners, and Editions.

The sum of the inertia of the two dimensions is 19.3%. This means that these two dimensions explain the variance of the same percentage of the observations.

The analysis allows us to identify at least two features (dimensions) of EduOpen MOOCs that characterize the design and delivery processes. The design dimensions that classify the courses relate to the kinds of organization of activities and the accessibility of contents. In course delivery, the dimensions to analyse MOOCs are the different diffusion and the level of participation in the activities.

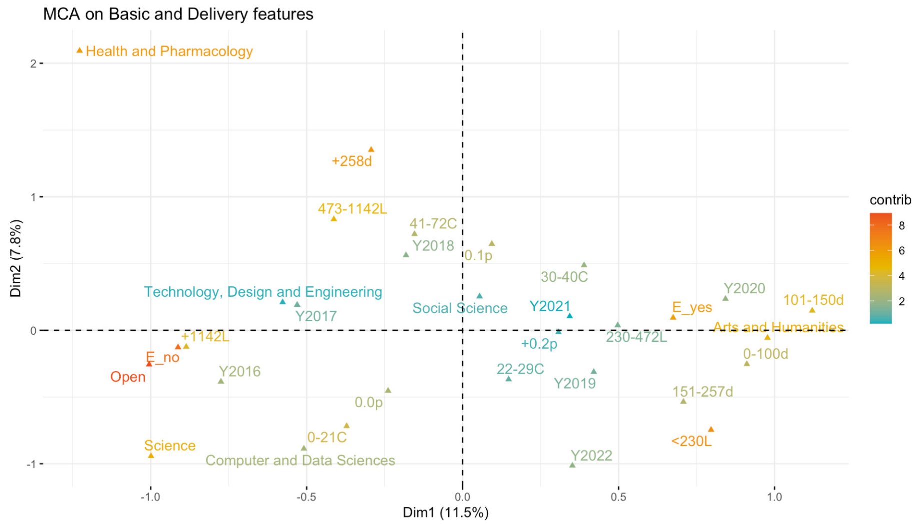

Fig. 2. Symmetric biplot of variables related to Basic and Delivery features of EduOpen MOOCs. Gradients show the contribution of each variable to the two dimensions (`ctr`).

In both cases, variable related to time in its various meanings Duration, Training hours, and Activities/Hour influence the two dimensions. We are used to dealing with synchronous, asynchronous, and self-regulation concepts, especially in blended courses [15]. MOOCs force us to talk about time factors as training hours and course scheduling that can change how students engage with contents [16, 17].

We added another more general observation in our discussion. Figure 3 shows the biplots for the categories of the variable named Course categories. In the graphs, the points represent the statistical units, and the colours in the legend define the categories. Our attention goes to the distance among categories. In the design biplot, courses related to scientific and technical disciplines are very close. Social sciences courses are in a different sector, and Arts and Humanities MOOCs are very distant from all the others on the left side. The same categories treated with the categories of the delivery variables take over another position. Health and Pharmacology courses are apart from all the others, and Science and Data Science ones remain near. Technology courses are nearer to Social science ones, and Arts and Humanities courses are now distant from the others but not as in the design biplot.

Similar effects can also be obtained by plotting the other common variables in the two analyses.

These two graphs seem to show an idea familiar to every teacher that proposes courses with the same structure or twice the same course: courses with similar design features could have very different levels of participation or diffusion when delivered.

As to Q2, MCA results show differences in MOOCs design and delivery over time in EduOpen. In Figs. 1 and 2, 2016-2017-2018 appeared in a different half-planes than the following four-year period. The splitting coincided with the period when the platform update was implemented. There has therefore been a variation in how courses

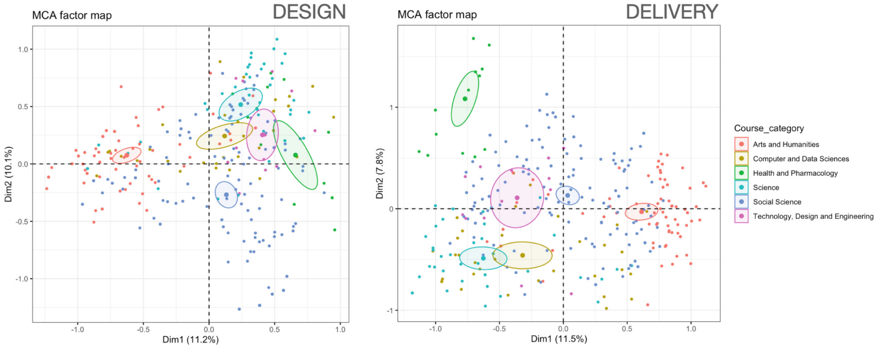

Fig. 3. Biplots for the categories of variable Course categories with Design (left) and Delivery (right) features. Points represent the statistical units and the colours in the legend define the categories.

were produced and delivered that could be related to the changes in the same platform, considering the influence of technical features on courses development. However, this break must be further investigated because it might also derive from more general issues related to the organisation of the network.

Besides, Fig. 4 shows two histograms: on the left, we can see the distribution of new learners registered from 2016 till June 2022; on the right, the distribution of courses by Starting year. The MOOCs in dark grey have only one edition; we find in light grey courses that were the following editions of a course.

In the first graph, 2020 represents an exceptional year for the number of registered users (about 30,000). We can hypothesize that EduOpen was used during the lockdown and Covid19 pandemic to satisfy training needs that universities and other entities had to meet or probably that training on EduOpen had been chosen as an activity to fill the empty moments due to the obligation of staying at home.

In the second graph, we can see that 2018 and 2019 were the years when more MOOCs were produced and published by the network institutions. However, in the same years, we observe an increase in courses with more than one edition. The distance between courses in light and dark grey was higher in 2020 and 2021, years of the pandemic, during which institutions were committed to the great challenge of online education and fewer (human and material) resources could be assigned to open education activities.

In reply to the second research question, we can say that platform updates in November 2018 didn't affect learners' participation but were part of an intense period of development of the platforms and seems to distinguish between two periods in the design and delivery of courses from the previous figures (Figs. 1 and 2). The effects of Covid19 pandemic/lockdown carried many new learners and a decrease in the universities' commitment to open education. The growth of learners in 2020 is consistent with the international scenario, which defines this year as the second year of MOOCs after 2012 [18]. At the same time, the opposite decrease in MOOCs production is a manifestation of the regional dimensions of EduOpen that didn't allow greater investment in production.

The number of MOOCs produced until June 2022 lets us think that the relatively stable health situation can bring a new engagement in MOOCs production.

4 Conclusion

Our analysis started from the consideration that studies on regional MOOC platforms as L@S environments can add information on the design and delivery of courses with respect to the more numerous research conducted at the international level. Using MCA, we analysed the courses published on EduOpen from 2016 to June 2022 to identify a latent structure in the design and delivery features of the courses that allows us to describe the actual status of the platform and identify interventions to better the courses.

Replying to Q1:

- we found two dimensions that define the structure that underlies the design process - COURSE DENSITY and CONTENT ATTAINABILITY, and the delivery process - DIFFUSION and PARTICIPATION. A limitation in the MCA is the values of *inertia* around 20%, which suggests that more dimensions have to be analysed to obtain more complete results;
- courses designed according to similar characteristics may have different delivery;
- variables related to time (Duration, Training hours, and Activities/Hour) influence the two dimensions identified in the design and delivery process.

Replying to Q2:

- in MCA results, the distinction on the half-planes among the years in Figs. 1 and 2 lets us think that course features are related to specific periods. The year of transition coincides with the technical updating of the platform. More investigation into this is necessary.
- Covid19 lockdown affected the number of new learners registered and accentuated a process already begun in 2019 of reduced commitment to the production of new courses by network institutions.

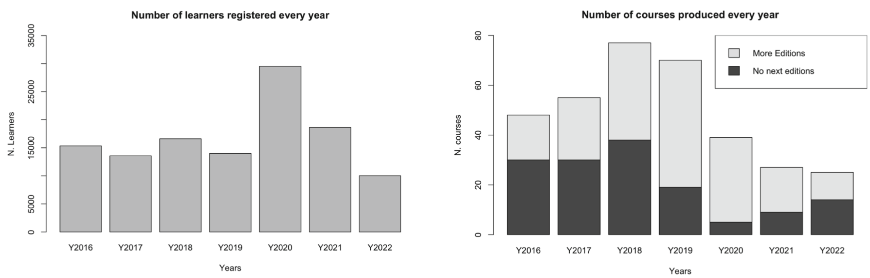

Fig. 4. Number of learners registered in the platform every year (left). Number of courses published every year; the light grey bars represent the courses that have one or more editions (right). Please, note that 2022 courses are considered till June.

Our study is set in the international scenario of MOOCs research where the production of papers is articulated around some thematic groups as institutional approach, pedagogical approach, evaluation, analytics, participation, and educational resources [19].

A previous study [20] analysed the design characteristics of more than 300 MOOCs in Portuguese using multiple correspondence analysis. Our research confirmed the use of this method for design analysis by applying it to MOOCs of a single platform. In our study, we were also concerned with analysing delivery issues along with design.

Some focal points that members of EduOpen (and not only) can consider to improve strategies in the design and delivery of the courses are related to:

- the awareness of the influence that the organization of activities and content in a MOOC can assume. In the first MCA on design, the contents are at the centre of the discussion for number, duration, amount of knowledge, and coherence with the whole course to which they refer. Future research can regard the relation between the features of contents and activities and the behaviours of learners in the courses;
- the attention to time-related issues that arose in the analyses with regard to the scheduling and duration of activities and entire MOOCs, course availability and estimated number of training hours, and changes over time;
- the reflection on levels of interaction of the courses that in this analysis confirm our previous results [21]. In fact, in the biplot in Fig. 1, the distance between the categories of course modes, tutored and self-paced, appears to be unremarkable. Participation in forum discussions, as noted in Table 1, is very low;
- the deployment of qualified professional figures for design and tutoring that are indispensable for enhancing and analysing the design and delivery mechanisms of the courses described here.

We can imagine a future for EduOpen to work in guidance, disciplinary and soft skills, recognition of credits, and mobility among universities. It has to start with attention to course design and scheduling, participatory mechanisms by learners, and the involvement of professional figures to design courses and support students.

Comparing these results with those from other (regional or global) platforms could be useful to generalize them or to characterize EduOpen with specific features associated with participants' cultural factors and design methods.

Authors' Contribution. The contribution represents the result of a joint work of the authors who collaborated in all the phases of the research work. According to CRedit system, Annamaria De Santis: Project Administration, Formal Analysis, Investigation, Writing – original draft; Katia Sannicandro and Claudia Bellini: Conceptualization; Tommaso Minerva: Supervision.

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Social Learning for Professional Development. A In-House Experimentation in Initial Teachers Training

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Abstract. Social Learning, as a social work practice [1] with whom developing students' skills, is a well-known methodology, in Higher Education too [2].

This paper explores Peer Tutoring as a form of Social Learning. The research field is offered by the first three years of the Peer Tutoring Program implemented within the Course degree in Primary Education at the Università Cattolica del Sacro Cuore, in Milan. Our hypothesis is that the program offers the students the opportunity to perform in advance the very important action of mentoring younger colleagues developing professional responsibility and problem-solving skills of teachers in their initial training. The focus is on peer tutors aiming to explore reflections and meanings originated from the experience of providing younger colleagues with competencies developed within the academic context and curricula. The research, conducted through a Mixed Methods Case Study Design, investigated peer tutors' internal perspective, focusing on crucial fields that are often missed by higher education curricula, as they cannot be explicitly taught, even if they represent the necessary condition to train professional teachers able to manage future challenges and scenarios unknown in advance.

Keywords: Social Learning · Peer Tutoring · Teacher Initial Training

1 The Project in a Nutshell

The proposal is intended to be as a teaching practice enabling students to learn from the experience of real-world context. Participating in the life of a community through active involvement and serving experiences methodically organized to meet the real needs of the context, students situate their learning beyond the classroom and within the community [3].

It is also known that the peer tutoring experience stimulates the relationship and dialogue between student and tutor since the student feels closer to the tutor for reasons of age and status. Furthermore, the peer tutor, motivated by his or her new role, makes his or her knowledge and experience available. In addition, a student who has experienced the same path as the freshman student to whom he/she gives help knows what difficulties can be encountered and the right advice to offer. At the same time, the

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freshman student who is approaching the university world has less difficulty in relating to the student who is currently playing the role of tutor, and he/she feels freer to ask questions, request clarifications, without being afraid of making mistakes and fearing to ask for things that are taken for granted and obvious. This model thus fosters the relationship and dialogue between student and tutor [4]. Tutee students can benefit from individual support - a scaffolding - from a colleague who has already faced and experienced a similar path; peer tutor students have the chance to put their acquired skills into practice, providing a service to the degree course community, feeling like facilitators and advisors towards their fellow students [5]. In Italy, Peer tutoring is also provided for by the law containing provisions for universities and research institutes, as well as on the licensing of professional activities[1].

Considering such scenario, a proposal has been articulated to respond to concrete needs, typically emerging in students attending the first two-years of traineeship.

From 2019 to 2022, a Peer Tutoring Program involved 208 pairs of student volunteers: from the fourth and fifth year as peer tutors and from the second and third year as tutees.

The recruitment of peer tutors and tutee is pivotal: for the former, the voluntary nature and clarity of the role to be interpreted are crucial, while for the latter, fundamental are the intention and interest in joining, even if initially directed by their traineeship tutor.

The next crucial junction is the peer tutor-tutee matching procedure; this is carried out by comparing the three thematic areas,[2] on which each peer tutor has declared his or her willingness to provide the service, with the three areas on which each tutee, in agreement with the traineeship tutor, requests support. The criteria that guide the matching are: the need areas set by the tutees and the ones stated by the peer tutors as strongest points; being or not a working student; being a special needs student. Crucial in this stage is the contribution of the traineeship tutors who, because they know each student individually, are able to provide each candidate with the information necessary for the purposes of successful matching.

The enrollment phase ends with the signing of the training contract by the peer tutor-tutee.

At the end of the provided service, once all the required contractual formalities have been completed, the peer tutor is given 1 additional CFU (University credit) with respect to the study plan.

Peer tutors' training is carried out through synchronous and asynchronous activities; the first ones edited and performed by the Staff; the others available in self-directed learning mode. A dedicated page in Blackboard serves that purpose.

Monitoring and sharing activities support the pairs during the whole service time.

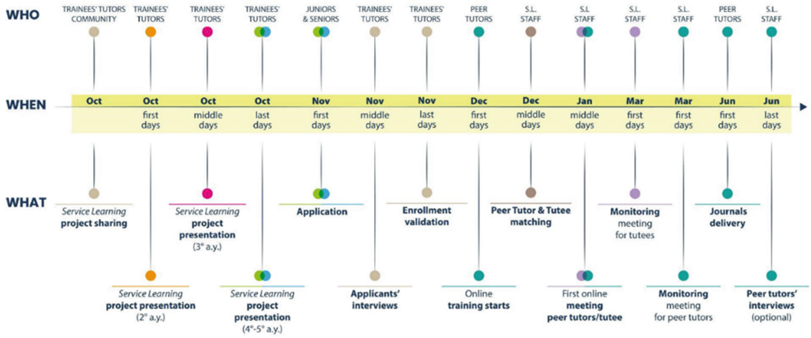
Designed to be held in a blended form, the program was held entirely online since the pandemic lockdown in February 2019. Initial design, the needed re-design, organization, and management were carried out by a Staff composed by two volunteer traineeship tutors.

The timeline below summarizes all the steps and the involved actors (Table 1).

[1] Law no. 170 dated 11 July 2003, art. 1.

[2] Peer tutoring can be provided with seven areas: teaching design, interaction with traineeship school, exams & laboratories, educational technology, Beginning Teacher Competencies Framework monitoring, e-Portfolio, end-of-year report.

Table 1. Peer Tutoring Program Timeline.



2 The Research

The focus of the study is on peer tutors, our hypothesis is that the program offers the students the opportunity to perform in advance the very important action of mentoring younger colleagues developing professional responsibility and problem solving skills of teachers in their initial training. The question we aimed to answer is about the meanings the peer tutor attribute to those dimensions, thus the study aims to look thoroughly into the contexts experienced by the peer tutors searching for their representations of responsibility and problem solving. The research was conducted through a Mixed Methods Case Study Design [6] to reach a first picture of the meanings and reflections reported from the peer tutors about their experience. Hence, we collected data from multiple sources, analysed them with consequent different procedures to realize a triangular reading of the outcomes.

1. Two hundred and eight peer tutors' diaries with notes, comments and metacognitive considerations about their experiences were analyzed with T-Lab. The texts were assembled in a corpus and analyzed, after appropriate normalisation, lemmatization, dictionary customisation and keyword selection, using the elementary context analysis function to perform (unsupervised) clustering. The T-lab algorithm (PDDP & bisecting K-means- ≤ 3 co-occurrences)[3] [7–9] performs a co-occurrence analysis and a subsequent comparative thematic analysis. The choice of processing the texts with such a clustering procedure served to map the existing isotopies, understood as

[3] This is a partitional clustering: objects are divided into non-overlapping subsets (clusters). Each object belongs to only one cluster. The reduction of the multidimensionality of the data is realised by the T-lab algorithm through SVD in order to find a smaller number of dimensions, onto which to project the original points, where these dimensions capture the greatest variation in the data (they maximise variance). The dissimilarity of the data is then represented as the distance between the points. The k-means processing algorithm (a non-hierarchical classification method) creates clusters by aggregating the items around a centre (mean) of the cluster; thus each cluster is centre-based.

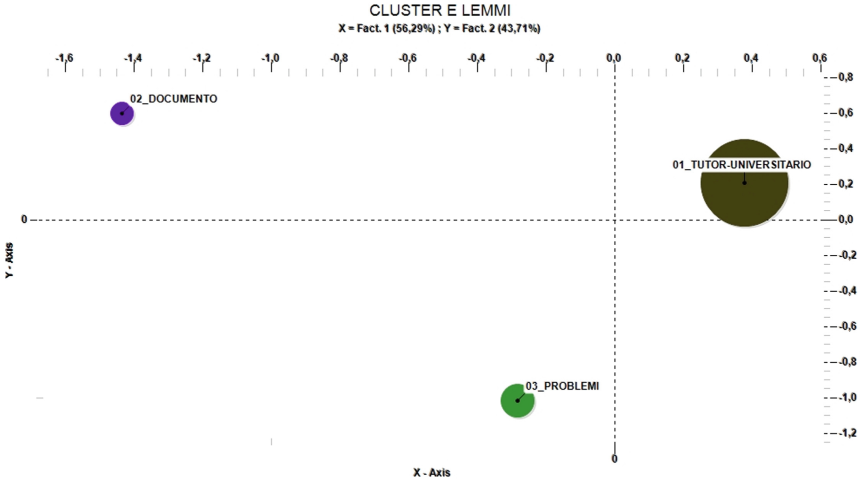
themes characterised by the co-occurrence of semantic traits. The exploratory purpose of the analysis led us to choose a procedure capable of extracting and clustering a given collection of unlabelled patterns, so that the clusters obtained were separated externally (maximum deviance between groups) and cohesive internally (minimum deviance within groups) [10]. The procedure offered by T-lab made it possible to select a priori the number of clusters to be extracted (as few as possible), which was decisive to bring out the common trends of highest occurrence on which peer tutors reflection focused. The procedure was performed twice, starting form two separate keyword lists, one for each of the two semantic field we want to explore: responsibility and problems. Once identified the semantic objects, the clusters were used, as stand-alone tools, to understand the objects distribution within a two-dimensional similarity map [11] capable of maximising distances between objects belonging to different clusters and minimising distances between those belonging to the same cluster. The choice of cosine square index [12] to represent them fulfils this requirement. Once the partition was obtained, the labels attributed to the clusters were the headwords with the highest chi-square value. The objects characterising each cluster were subsequently analysed by the researchers in the light of the list of Elementary Contexts selected by the software during the partition, to frame the semantic field within which the peer tutor declared to exercise professional responsibility and to address and solve problems.

2. Twelve explicitation interviews [13] held with peer tutors who accepted to discuss about the meanings of their experiences. The questions asked was simple and extremely open: "What would you relate to the word responsibility among the situations you faced during the peer tutoring experience?" The interviews were held online and recorded. The verbatims were analysed trough a discourse analysis looking for the sentences that made explicit the peer tutor's course of action when aware of a specific call for responsibility.
3. Twenty-four artefacts created by peer tutors for different purposes: sharing comments and suggestions with their colleagues that could be interested in taking part in the same experience soon; monitor their matching with the tutees. The artefacts were analyzed, in form and content, to select the ones that represent meanings referred to responsibility.

3 Analysis

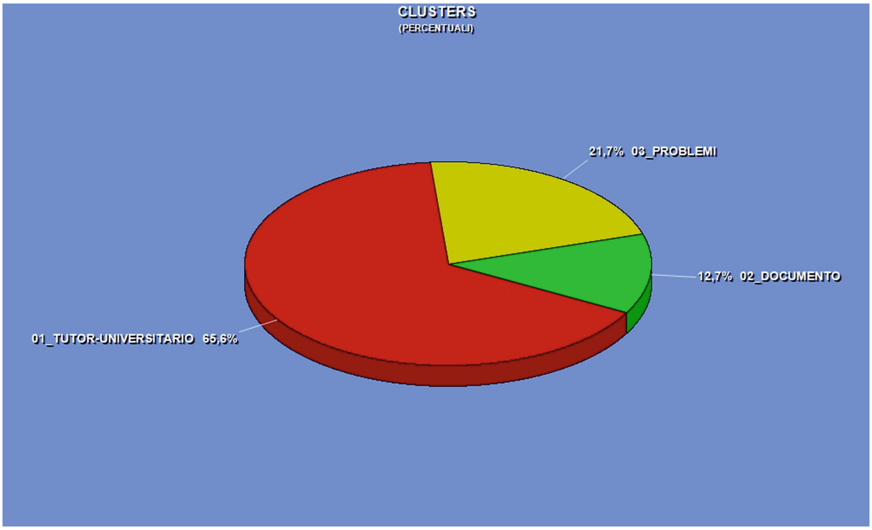
Addressing and Solving Problems (395 elementary contexts; 82 keywords). The MDS map (Table 2) illustrates the three clusters identified by the software, their mutual positioning in terms of distance, and their consistency in terms of the number of elementary contexts containing the keywords.

Table 2. The Clusters.



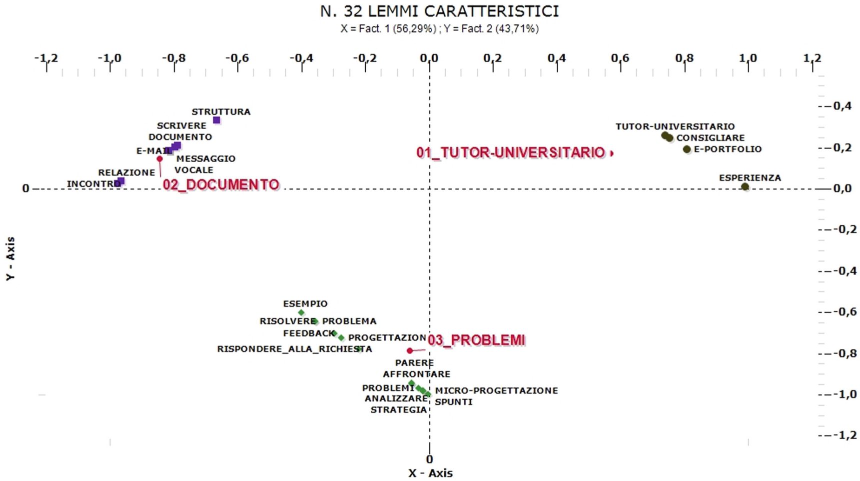
The aerogram (Table 3) specifies the percentages of the elementary contexts in which the keywords belonging to each cluster are present (Table 4).

Table 3. Clusters in terms of percentage.



In order to explore the problem-solving competence deployed by peer tutor, let us analyze the keywords of the clusters in the light of the table of meaningful contexts returned by T-lab.

Table 4. Keywords in clusters.



3.1 Cluster 1_Traineeship Tutor

The traineeship tutor and the experience of the peer tutor are seen as resources to draw on, particularly in the organization and drafting of the e-Portfolio.[4] The frequent reference to *skills*[5] refers almost only to their documentation in the e-Portfolio; in only one case does it refers to their deployment in direct training. The term *experience* refers in two cases to professional circumstances experienced by the tutee, for which documentation within the e-Portfolio is suggested. A widely emerging aspect concerns the strategy of the peer tutor to prompt the tutee to reflect on what has already been produced in the e-Portfolio or on the possibilities of its reorganization. The choices are diversified:

- verbal confrontation in which the peer tutor critically argues the aims and possible structures that an e-Portfolio can take on; in this regard, the peer tutor reported that they valued the tutee's choices but also relaunched and broadened the perspectives.
- request to share the tutee's e-Portfolio to analyze it and give specific feedback that the tutee can use autonomously.
- sharing their e-Portfolio with the tutee to generate an example comparison

[4] Students attending the Course degree in Primary Education at Università Cattolica del Sacro Cuore are requested, from the second to the fifth year, to edit and update an e-Portfolio to provide evidence and reflections in progress on their competencies. The students' e-Portfolio is periodically shared and discussed with the traineeship tutor. The e-Portfolio is delivered by Blackboard, it does not have a fixed format, each student is called to shape its own. The operating system is the only limit to the student's possible choices.

[5] *Skills* is referred to the ones listed in the *Beginning Teacher Competencies Framework* adopted by Università Cattolica Del Sacro Cuore.

– use in a synchronous moment of a structured tool, such as the e-Portfolio assessment rubric,[6] to make a self-assessment from which to obtain ideas for improvement.

However, in addition to suggestions for getting around technical difficulties (inserting artefacts, sharing on the platform), continuous references are made to the impossibility of producing a certain and unifying solution for the e-Portfolio, as a tailor-made professional development tool rooted in the skills envisaged by the Framework, to which the figure of the traineeship tutor acts as a backbone and a boost. The meaning of the keyword *advice* lies precisely within this last consideration: the offer of "another" point of view, in any case to be validated in the discussion with the traineeship tutor.

3.2 Cluster 2_Documents

The analysis of the elementary contexts of this cluster returns, first, the variety of documents discussed by the peer tutor and the tutee: end-of-year report, micro-project of practical traineeship, activation documents, development, closing of practical traineeship and the e-Portfolio. Cluster keywords essentially refer to the role played by face-to-face meetings (interrupted by the pandemic in February 2020)[7] and by the online communication/sharing tools used by the peer tutor to provide operating indications on the specific difficulties of their tutees.

3.3 Cluster 3_Problems

This cluster is the richest in keywords. The word *problems* is declined in problem addressing, problem solving, issue solving. In four cases, the peer tutor states that there was no problem to solve, with the following excluded from this category: "giving and receiving suggestions", "constructive exchange of ideas and advice", "reassuring about the feasibility of the work he/she was supposed to do". Generally, the peer tutor express a perception of security and serenity regarding the requests made by the tutees; in two cases they state that they felt anxiety in the first instances of first contact. To address and solve the problem posed by the tutee, they activated resources such as:

1. searching the Internet for operational cues to propose for micro-design
2. analysis of a construct and transposition into concrete examples
3. communication that conveys confidence and complete availability
4. requesting confirmations from the traineeship tutor to ensure that the answers are correct
5. discussion with colleagues considered authoritative in order to formulate answers based on shared elements
6. search among own materials for what has been achieved/studied in previous years
7. sharing of indications provided by traineeship tutors during the various years of practical training

[6] Tool created by the staff of the traineeship tutor under the supervision of the Course director, Professor P.C. Rivoltella.

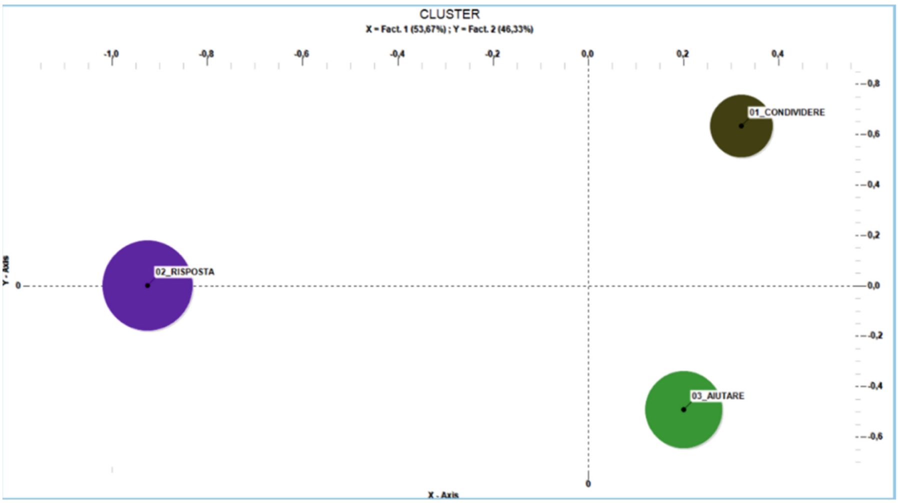
[7] The students of academic year 2020–2021 never met in person.

8. fielding of analogical reasoning when the problem to be tackled was similar to what had already been experienced in previous academic years
9. offering detailed feedback following the analysis of the e-Portfolio/of a design
10. offering opinions, suggestions, alternatives

What emerges from the analysis of clusters 1 and 3 shows is that the problem addressing and solving strategies were both strictly procedural and heuristic [14]. Those relating to aspects not merely technical/bureaucratic appear as Adaptive Decision Making [15] as much as conducted with various strategies, with results neither univocal nor aimed at providing "the right answer". The peer tutor must figure out, trough to a process of active listening of the request, a subsequent separation of research/reflection to formulate possible proposals.[8]

Exercising Professional Responsibility (285 elementary contexts; 80 keywords). The map (Table 5) illustrates the three clusters identified by the software, their mutual positioning in terms of distance, their consistency in terms of the number of elementary contexts containing the keywords attributed to the individual cluster.

Table 5. The clusters.



The aerogram (Table 6) specifies the percentages of the elementary contexts in which the keywords belonging to each cluster are present.

The map (Table 7) highlights the keywords belonging to the clusters.

[8] Most of the aspects regarding the students' e-Portfolio involve an Adaptive Decision Making since it implies a wide range of possible course of action. The choice is actor-centered and is guided by the actor's priorities.

Table 6. The clusters in terms of percentage

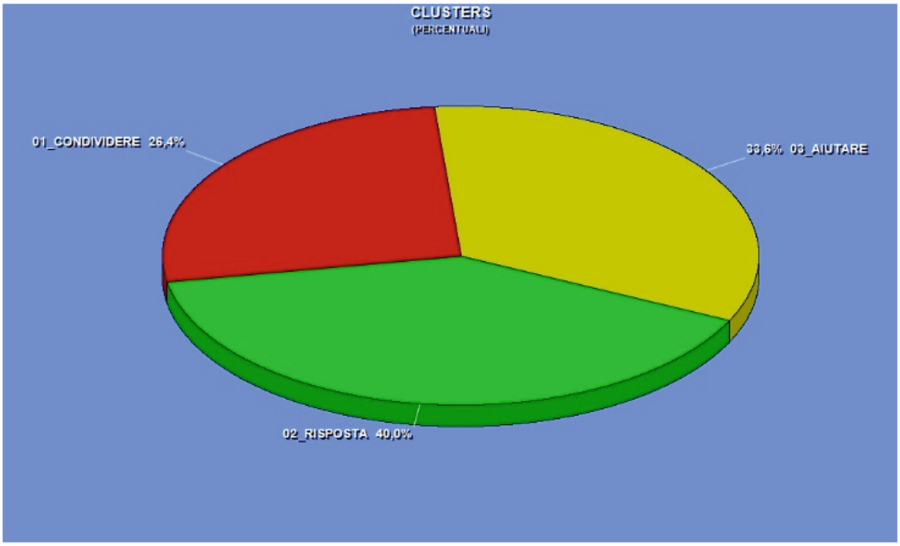
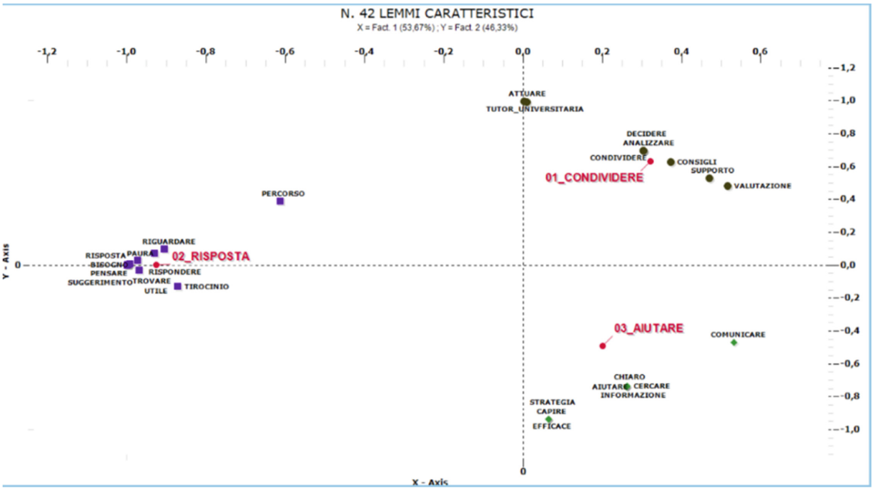


Table 7. Keywords in clusters



To explore the skill related to the exercising of professional responsibility by peer tutoring, let us first analyze the keywords of the clusters, in the light of the table of significant contexts returned by T-lab.

3.4 Cluster 1_Sharing

The *sharing* semantic field refers almost exclusively to the moment of sharing the tutee's e-Portfolio with his/her traineeship tutor. This awareness appears to generate in the peer tutor a strong sense of responsibility linked to two factors: the *evaluation* of the tutee's e-Portfolio by the traineeship tutor and the consequent need to configure the peer tutor's support as a careful analysis (*to analyze*) of the document on which *advice* rather than indications is given. Even in the two contexts in which the peer tutor formulates directions, he or she is careful to argue his or her statements, generating debate and discussion to ensure the tutee *shares* the same opinions. What emerges is the strong need for a precise analysis of the situation/document as the main form of *support*, but also a sort of uncertainty about the traineeship tutor's requests, which seem, at several points, to be perceived as discretionary or not easily foreseeable. In only two contexts is the perception of responsibility linked to the school context in which the tutee will implement the didactic design as a trainee.

3.5 Cluster 2_Response

Within the cluster, the keywords are linked to a perception of responsibility experienced as awareness of the weight of one's own words. Also present is the fear of not being up to the task of *responding* to the tutee's *needs* and the consequent need to *think,* to *look back* over one's experiences in order to find the contents to provide *useful answers* to the tutee's demands, but also to feel useful in the role of peer tutor. The word *pathway* appears as an outlier [16], it does in fact occur frequently but the semantic fields to which it refers are widely diversified, so it does not take on any specific importance within the cluster.

3.6 Cluster 3_Help

The elementary contexts selected by the software return the awareness of taking charge of the other (*to help*), of the need to manage a clear and effective communication (*to communicate*), of the empathy arising from reliving previously experienced emotions and difficulties in the other. Effective accompaniment appears to be linked both to the search for strategies and to a posture in providing information endorsed by sources considered authoritative and/or shared in the peer group. *Understanding* refers in almost all contexts, except one, to the non-judging, listening/accepting posture of the other and his/her needs, put in place by the peer tutoring.

4 Interviews Excerpts

The interviews were specifically aimed at elucidating students' perceptions of professional responsibility. These five excerpts show the different connotations referred to the word responsibility.

4.1 Saving tutees' freedom of thinking: "She was asking what she had to write about that…in my mind I thought: I don't want her to write what I would do, what I would think. I want her to find her way to reflect on her experience. So I asked her to allow me some minutes to think…then I asked: tell me what you learnt by that experience, how did you feel in that situation, how will you possibly use what you have learned…"

4.2 Sharing personal experience: "He was incredibly anxious, in few days he would have been in a class for the first time in his life and he had no idea how to interact with the children! I said: yes, I still remembered that feeling…is like being lost! I told him not to be concerned, since it was a common experience referred to that first time. I told him about my first time and then I suggested a couple of activities he could have done for ice breaking."

4.3. Founding answers based on reliable sources: "Every time I said: -Look you could do it like this- I had to justify myself and her about what I suggested, I had to reflect on identifying the roots of my words, because I had to be sure they were reliable."

4.4 Awareness of the power to make the difference: "After her question I realized how much responsibility I had on my shoulders: my answers will have made the difference between failing or succeeding!"

4.5 Developing problem solving strategies "I had no answer to her question…I propose her to analyze the problem together from different points of view, using the six thinking hats strategy [17] then we compared the outcomes to the sources we had at our disposal and made a choice based on their reliability."

5 Artefacts Selection

The artefacts portray peer tutors' reflections in the decided form to share them with colleagues and Staff. They represent four categories:

1. What did I gain from the experience?
2. The peer tutoring logo proposal
3. The peer tutor features
4. What a peer tutor can offer

Here are the emblematic ones for each category (Table 8).

1. The artefact represent the achievements that peer tutor selected among the reached ones: awareness of responsibility, reflection skills, sharing will, listening and tuning in, a new friend.
2. This motto points out the positive interdependence between peer tutor and tutee. The four ds: in English they become the four gs: *I give since you give, you give since I give*. The formula like words within a circular shape with suggests that positive interdependence is the only way to carry successfully out the relation between peer tutor and tutee.

Table 8. Selected artefacts

3. Tuning in, communication, sharing will, expert suggestion. The artefact is interesting in comparison with the first one: it declares a sort of *minimum standard* for applying the role to guarantee the tutee satisfaction.
4. It is the answers jar that says: "I am available, I am here for giving answers, take a chance on me!" The jar pictured as open and the slogan on the label reciprocally reinforce the uniqueness of the message.

There is also another kind of artefact made by the students: the diamond rankings (Table 9). We used to do a survey among the tutees to know which peer tutors' attitudes they felt more supportive; then we ask the tutees to rank them. The one on the left side was realized during a monitoring online meeting. In a following meeting, the peer tutors were asked to rank the same attitudes (the diamond on the right side). These are the two resulting rankings: five items, the green ones, overlap. We have a slight difference of position related to four items, the ones in different colours.

Table 9. Diamond rankings

6 Conclusions

Materials coming from different data sources converge on the connotations given by the peer tutors to the dimensions under investigation. In the exercising of responsibility, the prevailing semantic fields concern caring, the perception of one's own limits, the awareness of the potential effects of one's own words/actions, and the need to validate possible answers through comparison with sources considered authoritative. These elements outline the category of relationality as the central feature of responsibility. This trait gives us back the fielding of a professional skill that grasps the cross-reference which the possible meanings and etymologies of the term responsibility have in common: intersubjectivity and reciprocity [18]. The acknowledgment of a required effort to be tuned in and support the other without replacing or taking over him/her suggest a responsive approach to the responsibility. These meanings extend beyond the contingent temporal dimension: the creation of artefacts for the purpose of sharing one's reflections in the community platform also shows a commitment to contributing to the training of future peer tutor and a willingness to manifest to tutees the ethical and operational posture of one's role.

Even the conversion from a blended model to a fully online one, following the first Covid19 lockdown, allowed the peer tutor to effectively implement the relationship modalities in an *onlife* logic [19]. The action of the peer tutor responded to the commitment in which the level of individual ethics is intertwined with interpersonal ethics [20], creating a third space [21] of negotiation of the meanings for all the players involved.

About addressing and solving problems, it is interesting to note that peer tutors were able to offer a wide range of organized and finalized behaviors, all supported by processes of analysis, research, validation, reflection and dialogue with tutees. Significant is the reference to previous experiences that do not qualify as knowledge to be merely applied but as experiential bases on which to found reflection or from which to exercise analogical thinking. The addressing dimension is also interesting when it concerns the fear of not being up to the situation, which is transformed into a search for strategies and validation, through comparison with the resources available within the community.

Our findings seem to support our premise that Peer Tutoring is a crucial activity in initial teacher training to exercise problem solving skills and to enhance professional responsibility in the meanings of taking care and making the difference. Furthermore, mentoring peer to peer allows the students to learn the meanings of responsibility on the field through a form of experiential learning [22].

The main limitations of the work relate to the quality of the data collected and their comparability. First, there is the quantitative/qualitative inhomogeneity of the materials: the texts extracted from the diaries concern the experience returned by all the peer tutor, whereas the interview texts come only from a small number of volunteers who were willing to give them. Artefacts are not only textual and are also limited in number. Furthermore, the interviews were conducted by the same individuals involved in the management of the Peer Tutoring Program. This, by ensuring a familiarity between interviewer and interviewee, could have produced both a focus on the themes proposed by the questions and a distortion due to the need to give back a desirable image of their role on the part of the peer tutor.

Finally, the problem exists of the quality of the clustering, which, in this partitioning mode, is difficult to restore by simply consulting the indexes [23], the degree of acceptability of which remains largely up to the researchers, especially in cases where clustering is the starting point for subsequent statistical analyses. In our case, the problem is actually very limited as clustering was not used for subsequent statistical analyses but as a classification model to identify the declinations of the two investigated themes that most frequently appear in the peer tutor narrative.

Reflections and meanings, coming from peer tutor in our study, pinpoint a picture that should be explored in future research based on quantitative methods. It would be interesting to know:

- How many former tutees apply to become peer tutors and why.
- How many former peer tutors use the skills acquired through the service in their daily work at school.
- Which of those skills are most involved in school teaching.

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Audiovisual as an Atelier. Theoretical Framework and Educational Applications

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Abstract. An extensive scientific debate highlights the functions of audiovisual in media educational and teaching fields, individualizing some specific cognitive, imaginative, and emotional aspects. With respect to this debate, this article aims to introduce the idea that video could be considered as an atelier. This means to think about audiovisual as a space into which could be possible for people to build up original creations, share ideas, develop personal vision of reality. All this concerns a generative concept of video as an experiential environment. The second part of the article explains what this means and shows three possible uses of video thinking in the field of educational research, teacher training and classroom activities. The first one - *synaesthetic video* - explores the expressive opportunities offered by audiovisual language; the second one - *metonymic video* - recalls distant meanings, narrates concepts not by direct representation but by suggestion of memory and thanks to emotions; the third one - *metaphorical video* - uses a language closer to poetry than to prose, with the prevalence of symbolic features.

Keywords: Teacher's training and activities · Media Literacy · Visual Education

In this article we intend to reflect about the educational uses of audiovisual. Particularly we would like to support the idea that it can work as a creative atelier. Our analysis starts from a definition of the concept of audiovisual (par.1): it does not concern its expressive materiality, but the type of perceptive experience (audiovision) produced in the user. The functions (observational, documentary, narrative) and the environments within which it can be developed and used are then indicated. Naturally, video also represents a great opportunity to give shape to creativity (par. 2) offering itself as a possibility of writing, especially in the perspective of a critical building of knowledge. This is the case of the

This article is the result of a research project whose scientific responsibility lies with Pier Cesare Rivoltella and of which Alberto Parola and Chiara Panciroli were responsible for the research units of their own universities. The idea, the contents and the internal organization must be attributed to all the authors. Pier Cesare Rivoltella materially wrote Sect. 1, Alberto Parola Sect. 2, Chiara Panciroli Sect. 3, Anita Macauda Sect. 4 and Laura Corazza Sect. 5.

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atelier, considered as a creative aesthetic experience: audiovisual can be considered just as an atelier (par. 3) The last two paragraphs (4 and 5) provide some examples of the use of video considering atelier as a method of knowledge, articulating them in the three categories of synaesthetic, metonymic and metaphorical videos.

1 A Theoretical Framework

The evolution of media forms in the context of the so-called post-media society [1] involves a conceptual repositioning of many of the concepts that still seemed to work until a few years ago. One of these concepts is that of audiovisual. In fact, it is subject to a process of liquefaction: it loses definition with respect to its edges, it becomes contaminated, it risks being applied to any media experience. In this paragraph we intend to start from this fact, reflecting on the characteristics that define audiovisual today. Secondly, we will deal with its functions in the educational field. Finally, we will mention the digital environments in which it is possible to experience audiovisual, both in terms of production and use.

Talking about audiovisual liquefaction refers to how difficult it is today to recognize it from the point of view of its materiality [2–4]. This is due to the syncretic nature of audiovisual and its codical heterogeneity. Speaking of a syncretic nature means referring to the fact that audiovisual today consists of different communication modes [5] integrated in an articulated but substantially homogeneous form: just think of the widgets of a Web page, or the different frames that make up a story in Instagram. This syncretism is accompanied by a structural heterogeneity of the codes used: this makes audiovisual a complex semantic universe [6].

In the pre-digital era, before the introduction of multimedia and the Web, audiovisual was defined as a media founding its specificity in the coexistence of an audio track and a video track [6]. If this criterion were adopted, in the light of what we have said, today there would be really a few things that cannot be defined as audiovisual (a website and a YouTube channel, a video game and a TikTok channel) and this, as it is possible to understand, it would involve running the risk that everything (or nothing) is audiovisual.

For this reason, we have recently proposed [7] to change our point of view by proposing a definition of audiovisual that is not based on its materiality, but on the type of perceptual experience that it allows. Basically, today, rather than talking about audiovisual, thinking about a specific media form different from the others, it seems more appropriate to think about audiovision [8], that is a perceptive experience involving both viewing and listening and that expands more and more significantly even to the tactile experience. This shift from expressive materiality to perceptual experience is confirmed by the embodied orientations of neuroscientific research which, precisely in terms of audiovisual use [9], has advanced the hypothesis of an embodied simulation that would lead the subject, thanks to its mirror-system, to experience on the neuronal level the same emotions as the characters moving on the screen.

In synthesis, the "specificity" of an audiovisual does not depend on the type of technology or materiality, but on the skills of the user, on the social behaviors, cultures and institutions conditioning its production and circulation [10].

Defined in this way, what functions can audiovisuals perform in the didactic and media education fields? It seems to be possible to answer that these functions are essentially three: observational, documentary, narrative. Let's see them individually in greater detail.

The observational function refers to the possibility, through video, of observing elements or situations, taking them as an object of analysis, placing them at the right distance so they can be reviewed [7]. In the educational and didactic context, this need is met by movie sequences to be analyzed from the perspective of the case study or the analysis of the critical incident, but also the recording and retrospective analysis of simulations or real shots of teachers in a classroom situation. This is an audiovisual feature particularly used first in microteaching and then in practice analysis: a teacher is asked to give a lesson or to simulate it, it is filmed and then the video is used as analysis material, through discussion in explanatory group or interview [11].

The documentary function identifies in the video a very powerful tool to fix practices and experiences carried out. From this point of view, video contributes to pedagogical documentation by updating its format and integrating it from an expressive point of view. The "paper and pencil" documentation, in fact, was forced to go through a transcription process that involved translating what was observed into grapho-verbal codes through a process of description that often compromised respect for the materiality of what was observed. Video obviates this problem. Furthermore, the video-documentation is dynamic, it can be easily updated and integrated, it lends itself to retrospective analysis [7, 12].

Finally, audiovisuals can play a narrative function. Narratives, unlike description, open up greater spaces of creativity and push the subjectivity of the point of view from which things are told [7, 13]. The result is a personal product in which it is possible to identify representations and projections of those who made it. This makes storytelling video very interesting from a research point of view.

A final emphasis requires Digital Learning Environments which are used to develop visual and audiovisual narratives [5, 14–16]. The research distinguishes four types of environments:

– Digital environments that support learning through the use and production of visual and audiovisual resources [5, 15].
– Digital environments that support the development of visual intelligence and graphic intelligence through visual-iconic and visual-graphic forms [15, 17].
– Digital environments as socially produced spaces, places of meeting and reflection in which knowledge, experiences and relationships change and evolve [18].
– Digital environments as third spaces in which to aggregate materials from experiences lived and created both in real and digital space [14, 19–22].

2 Video as a Form of Epistemic Writing

According to what we told in the previous paragraph, we can think of how video today, especially at school, is accompanied by a considerable amount of potentially extraordinary opportunities in terms of reading and writing. Buckingham in his *Manifesto for* *media education* [23] indicates some interesting ideas related to "visual texts", suggesting that the starting point could be the multi-literacy model of Cope and Kalantzis «according to which teaching and learning are the result of the interaction of four literacy practices» [24, p. XVI]. These are: (1) the contextualized practice, in which pupils learn by doing; (2) the direct instruction for the development of spontaneous skills; (3) critical framework to allow the distancing of the student, to then extend it to a wider social framework; (4) and, finally, the transformed practice, through reflection and awareness. This means that, today, working in the classroom with video should no longer provide for a passive use (i.e., in front of an IWB), but an interactive mode thanks to which students interact with the IWB itself, allowing them a direct approach to technology and content. It is no coincidence that John Hattie, the father of EBE, argues that the "passive" video is considered a "weak" and non-generative element in teaching practice (translated into effect size below the average threshold of 0.4) [25, p. 54], while "interactive" video (which allows for example to shoot some scenes and interpret them within the entire narrative), is built and/or enjoyed also thanks to the movement linked to the ability to develop knowledge and skills through body movements. This dynamic is judged by its meta-analysis as a choice of method that allows you to learn better, favoring an enactive approach to teaching.

We maintain that video, better to be considered a technological object and a functional tool, is a perceptive experience and a creative language potentially generative of various kinds of skills. From here we start again to tackle the concept of epistemic writing linked specifically to the possibilities of the visual. The model indicated above interacts with the model of Bereiter and Scardamalia [26], then reinterpreted by some Italian authors, including De Beni [27, p. 169) and finally, currently, by Parola and Anichini [28], reorganizing it in relation to the matching between analogical writings (which here we consider traditional) and media/digital, both in the pure approach (only media or only digital), but also in the spurious mode, which highlights the mixture of approaches, methods, tools and products.

Starting from associative, performative, communicative, unified and epistemic writing we have further reasoned [28] to verify a structural adaptation (four levels and no longer five), but also interpretative in relation to the definitions and contexts more oriented, in this phase, to media writings [29] and digital ones.

3 Audiovisual as an Atelier

An educational reading leads to consider audiovisual as a creative atelier, an equipped training space, aimed at experience, in which to give rise to processes such as observation, design, manipulation and experimentation. It is in the atelier that new methods of re-elaboration of experience are set, characterized by the intersection of discursive, iconic, sound, symbolic practices and forms of incarnation. The resulting experience has an aesthetic nature: the ability to feel is strongly linked to understanding and interpretation. It is precisely this aesthetic nature that enhances this interdependence, based on a sensitivity of the relationship [4] or, with the words of Bateson [30], on a pattern that connects. In reference to this experiential dimension, iconic and sound forms of the audiovisual weave a sort of sensitive warping made up of multiple actions interacting both internally and externally and generating other connections [31]. The resulting audiovisual experience is the expansion of the perceptual feedback that embodies the experience of use. These aspects are confirmed by neuroscientific research which demonstrates how the audio-vision experience does not consist in the simple individual recording of a stimulus but in an interactive, articulated and deeply embodied social process, the result of collective training. In the atelier the subject relates himself to the others [32] through his own sensory apparatus and, in a space-time unfolding, participates in the becoming of dynamic and interacting forms, of sensitive-emotional solicitations and of phenomenal, interpretative and cognitive elaborations [33].

Atelier allows you to rethink the experience as an aesthetic experience, that is, as the possibility of recovering and enhancing the perceptive value in educational contexts that expresses itself in the sensory contact of audiovisual objects with the subject and with the communities co-participating in its creation. In this regard, we speak of open and plural design in which the audiovisual represents a collective art form [34] through a sudden break from everyday experience.

Audiovisual as an atelier allows us to grasp some main transformations in a historical, cultural, social, as well as pedagogical discourse, to understand specifically how the audiovisual space evolved towards a broader landscape in which sound and image are organically fused for composing a complex and dynamic system to give rise to original narratives giving value to the aspects of communication, participation and relationship. Noise and music have paved the way for a multisensory perception of space, in which the environmental character of the sense of hearing is crucial for the immersion of the viewer. It is precisely the notion of soundscape, introduced by Schafer [35], which has allowed us to reflect on the landscape as an element that is not only visual.

Within this multiple unity, the viewer of the audiovisual image can experience empathy and an authentic fusion with the landscape itself, immersing and transmigrating in it, identifying and becoming part of it, in a man-cosmos reciprocity. In this framework, the chromatic element can intervene to integrate even more intimately, and one could say almost symphonically, the viewer's sight and hearing. However, a need for sound images is increasingly emerging, able to lead us in these experiential landscapes to overcome an anesthetic indifference towards the landscape itself.

In this sense, the atelier proposes itself as a meta-space, with a multiform nature, which connects different spaces: digital and physical, personal and community, natural and artificial, conceptual and imaginative; and also spaces of social and cognitive relationship, near and far ones. Interesting in this regard is the point of view of Ortoleva [36, p. 298], which in the analysis of current media, with a specific reference to Youtube, describes audiovisuals as commonplaces, «in which millions of subjects learn every day, by trial and error to live, to move, to establish relationships, adapting the environment to one's needs and at the same time adapting to the constraints it establishes». The experiences that take place in the relationship between these many spaces lead to the definition of an audiovisual landscape, which does not exist in itself, but takes shape when someone who observes it, inhabits it, builds it [37].

The creative atelier in its phygital nature is therefore configured as an increasingly open and connected workshop space. Through a narrative approach, installations are proposed that can be traced back to several expressive forms which, while manipulating the same substance (photography, street art, cinema, music, poetry…), redefine and transform contents, recounting original aspects. The attention is focused on some fragments, spatially and temporally distant, providing a new and semantically dense rereading. Starting from discrete, meaningful and significant units, atelier builds up new educational paths, made possible by the technological dimension of this space, which can be traveled in several directions, giving rise to a non-univocal fruition, but of a reticular and associative type, which opens up multiple interpretative possibilities [38].

4 Audiovisual Atelier as a Method of Knowledge

Atelier, as we saw in the previous paragraph, means "laboratory, workshop, studio", referring to the work of artisans/artists (painters, sculptors,…) up to the most modern creators (digital artists, graphic designers,…) of works multimedia of an increasingly intangible nature, from photography to video installations. Specifically, there is a progressive dematerialization of the artistic product for the benefit of a visual and audiovisual sensory experience that is completed and acquires meaning in the relationship with the observer/listener [39]. According with what Merleau-Ponty says about the relationship between the subject of sensation and the sensible qualities of the world: «Le sujet de la sensation n'est ni un penseur qui note une qualité, ni un milieu qui serait affecté ou modifié par elle, il est une puissance qui connaît à un certain milieu d'existence ou se synchronise avec lui» [40, p. 288]. The observer/listener of an audiovisual experience becomes in some way also a co-author. In this sense, the video constitutes a great opportunity to give shape to creativity [7] and to contribute to the construction of new meaningful relationships, configuring itself as a method of knowledge. Etymologically "research, investigation, investigation", the method refers to a "way of research" [41] which in the audiovisual as an atelier innervates both the production/use and reading/writing process. The video thus understood, quoting Deleuze [42, p. 30] «is not a means of recognition but of knowledge», centered on a series of visual impressions that «forces us to forget our logic and retinal habits». In this sense, three examples of videos are presented here, attributable respectively to synaesthesia, metonymy and metaphor [43]. The *synaesthetic* video inscribes, through appropriate technicalities, within a text structured on two different languages (visual and auditory) elements that refer to sensorial spheres of a different nature so as to offer unprecedented possibilities of perceptual realization ('I see' a sound, 'I feel' a color,…) [44, p. 39]. The *metonymic* video refers to an expressive linguistic procedure, which consists in the transfer of meaning from one image, the real one, to another evoked in the subject's mind based on a specific relationship of semantic contiguity (the container for the content, the material for the object, etc.). The *metaphorical* video is based on an implied similarity, that is, on a relationship of partial semantic superimposition: a frame is used, through an action of transfer/shifting of meaning from one dimension to another, to communicate a different concept from what it apparently expresses [45].

The synaesthetic video

The "aRtelier" video, which is part of the type of videos defined as synaesthetic, focuses on the activities developed by children aged 3–6, in the context of specific expressive-sensorial workshops proposed by the Municipality of Bologna. The courses offered are part of sensory education projects focused on experiences of light/color and sound/silence through an approach based on exploration, creative assembly and construction of materials. The spaces are set up so that children can freely observe and learn about objects, shapes, colors, sounds and express their emotions through the use of multiple languages. There are few constraints, and the rules are simple. Children are free to paint and color, get dirty, make noise and listen, immerse themselves to experiment, feel, analyze and elaborate [46]. The "aRtelier" video is the result of a significant design activity carried out by a team of synergistic and coordinated professionals, made up of pedagogues, educators, teachers and experts in the cinematographic language with the aim of experimenting new forms of audiovisual narration of educational paths proposed within the laboratories. For the construction of the video, lasting a total of 15 min, 20 h of activities were filmed both in the nursery and in the kindergarten. For video recordings, specific choices have been made: camera placed at child's height, close-up shots, use of the subjective and the semi-subjective. The goal is to return the point of view of children, their actions, the effects of their movements and their gestures, interactions with objects and with the environment (Fig. 1). However, "aRtelier" abandons the traditional format of didactic documentation to explore the expressive-synaesthetic opportunities offered by audiovisual language. The content of the video itself, focused on the live recording of the sensory exploratory activities carried out by children, calls for a meta-reflection on the synaesthetic potential of the audiovisual. In fact, it is the audiovisual itself that talks about audiovision, showing how it can make other sensory forms see or feel and leaving the subject with the task of reconstructing and creatively weaving the semantic threads that connect new perceptual emergencies.

5 Process, Product and Educational Design

Continuing the analysis of the types of videos that we have built in an "Atelier" context and which we propose to use in relation to cognitive objectives and learning outcomes, we come across a video format, what we have defined as "metonymic", which allows you to work in the didactic field to develop meta-cognition, analysis and reflection skills.

Metonymic Video

On the occasion of the launch of the digital exhibition "Di Terra, di Cielo e di Mare", curated by the University of Bologna and the Vatican Museums, we made a short video, lasting min. 1.49, with the aim of arousing curiosity about the proposed theme (Fig. 2), explored through a completely online exhibition that has become «a journey through the Vatican and Bolognese collections to understand how the explorations and discoveries, which began in the Fifteenth Century, have affected the representation of Earth, Sky and Sea highlighted in planispheres, maps and globes» (In Internet, URL: https://www.doc.mode.unibo.it/sale-blu/di-terra-di-cielo-e-ofsea).

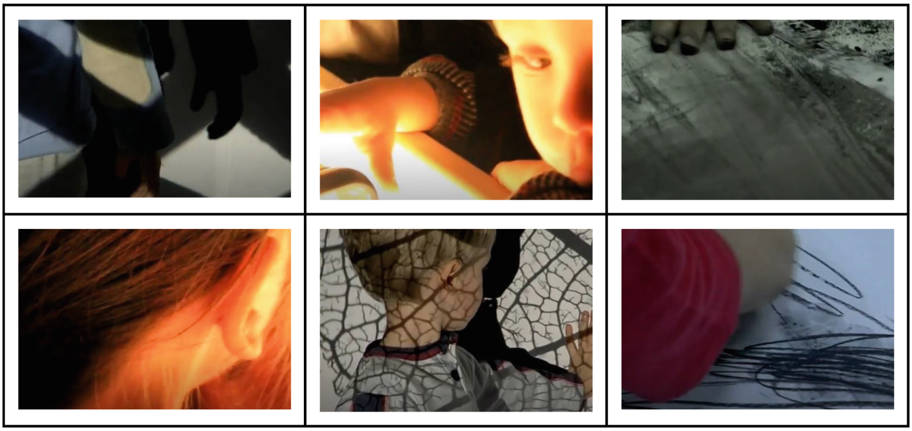

Fig. 1. Images correspond to as many frames extrapolated from the *aRtelier* video, created by MELA Laboratory of the Department of Education, University of Bologna. URL: https://www.youtube.com/watch?v=uuWdGb5yBZw&t=319s

Video features a globe-shaped ball, which comes to life and runs along the road that leads to the Astronomical Museum of the Specola, belonging to the Museum System of the University of Bologna. A little girl, fascinated by the moving object, follows it to the room of globes that recall sounds from distant lands and seas to her mind. At the end, the globe thrown into the air, concludes the path that leads from the land and the sea to the sky, indicating the three environments narrated and represented by the globes on display for the exhibition. The audiovisual language takes the viewer to a distant world, to the lands and seas depicted in the globes and evoked by the sounds and noises of exotic environments. However, it also projects upwards, with a launch towards the sky, which opens the gaze towards a horizon to be rediscovered. An evocative video also fulfills this function: it recalls distant meanings, narrates concepts not by direct representation but by suggestion of memory and thanks to emotions.

In the teaching context, such a structured audiovisual is particularly useful, thanks also to the emotional stimulation, to develop those skills of analysis and metacognitive reflection that allow you to recall individual information, insert it into a general information context and stimulate the formation of knowledge.

Metaphorical Video

Metaphorical audiovisual communication uses a language closer to poetry than to prose, with the prevalence of symbolic features. "Cinema of poetry" is what Pier Paolo Pasolini identifies as an audiovisual production strongly characterized by editing: the final product is a fusion of expressive elements of various kinds such as photography, movement, sound, music. Unlike "prose cinema", in which the story prevails, here the narration is not the main goal of the video, which instead is aimed to recall meanings and emotions for soliciting personal imagination [47]. In our production experience, as part of the media education lab of the Department of Education at the University of Bologna, we

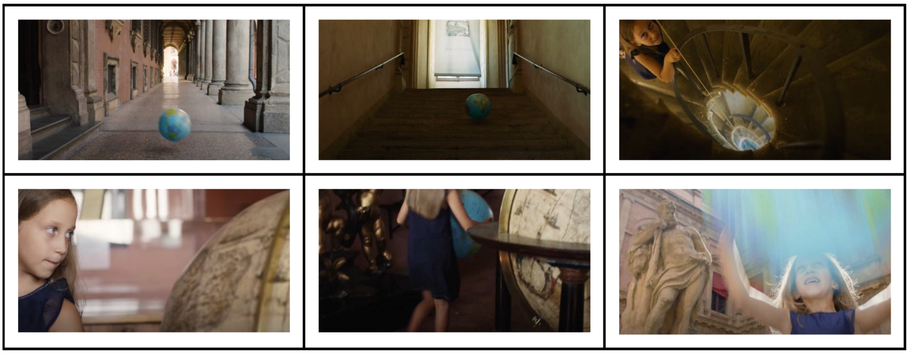

Fig. 2. Images correspond to as many frames extrapolated from the video "Di Terra, di Cielo e di Mare", created by MELA Laboratory of the Department of Education, University of Bologna, for MOdE, on the occasion of the inauguration of the exhibition with the same name. URL: https://www.youtube.com/watch?v=BKWXq-NALds

have often experienced this type of language, both in feature films and in short-term videos. This category includes the launch video of the new release of the MOdE, a completely digital museum that has the aim of communicating its virtual, interactive and collaborative nature, to encourage reflection on the opportunities and peculiarities of online museum displays. The trailer was designed to activate the viewer's imagination, called to build his/her own meaning as a digital museum starting from some suggestions-stimuli. Intentionally devoid of speech and accompanied only by a sound commentary, the montage focuses on the images encouraging us to search for personal meaningful relationships (Fig. 3).

Fig. 3. Images correspond to as many frames extrapolated from the video "The girl and the butterfly", created by MELA Lab of the Department of Education, University of Bologna, for the inauguration of the new release of the MOdE - Museo Officina dell'Educazione. URL: https://www.youtube.com/watch?v=Ch_Ikczkt-M

Including the vision of this kind of product into a teaching context means having as goal the development of high skills; Bloom considers them as the more complex skills, while Anderson and Krathwohl [48] put them at the top of the learning pyramid. These are creative and ideational skills, requiring the ability to understand, analyze and rework, adding however the goal of innovating the application of already known structures or devising new ones.

We have summarized the proposed teaching use of the three categories of video in a table, which aims to highlight the role of the viewer and the expected learning outcomes with the characteristics of each type of audiovisual (Table 1).

Table 1. Summary table: cognitive goals and expected learning outcomes in relation to the type of audiovisual product.

	WHAT VIDEO DOES	WHAT THE VIEWER DOES	LEARNING GOALS AND LEARNING OUTCOMES	WHAT TEACHER DOES
SYNAESTHETIC VIDEO	stimulates perception by offering an amount of detail	encodes perception (collects information and processes it, attributing meaning)	storing information and understanding	*structures the project, integrates different strategies, stimulates active learning*
METONYMIC VIDEO	it brings meanings back to the mind	reflects and reconstructs an information flow	analyze, decompose and reassemble	*structures the project, integrates different strategies, stimulates active learning*
METAPHORICAL VIDEO	stimulates imagination	starting from information data, it seeks new meanings to build a relationship of meaning	evaluate information data, imagine, create meanings	structures the project, integrates different strategies, stimulates active learning

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Supporting Instructors with Course Attendance and Quality Prediction in Synchronous Learning

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Abstract. The massive adoption of artificial intelligence has opened up the opportunity for a range of intelligent technologies that can support education. Empowering instructors with tools able to early predict the attendance and quality of their courses and consequently make prompt adjustments is one of them. However, the potential of these tools has by no means been researched exhaustively within synchronous courses, with prior work mostly focused on courses based on pre-recorded lectures. In this paper, we examine the predictive power of machine-learning models on the future attendance of students to synchronous courses and their perceived quality. To this end, we leverage both (i) attendance records to online real-time lectures within courses of a large public university, and (ii) responses to course quality questionnaires completed at the end of each course. Experiments show that our models can accurately and early predict attendance to courses and key aspects characterizing course quality (e.g., study workload). Our findings confirm the potential of intelligent models to support instructors in managing and promptly reacting within their courses, to increase engagement and reduce dropout.

Keywords: Learning Analytics · Machine Learning · E-Learning

1 Introduction

Context. With the development of digital technologies, many universities have started to evolve their way of offering synchronous courses, with some (or all) of them even given online. Synchronous learning, defined as a real-time, instructor-led learning experience where participants are connected at the same time and communicate with each other, is indeed a widely adopted teaching modality [10]. Since the lecture is active, students can ask questions and receive answers immediately. Likewise, the instructor can assess and shape students' knowledge in real-time. For instance, [6,7] compared a fully face-to-face format with a novel online synchronous course format, with respect to students' learning outcomes and their level of engagement. Notable studies, such as [14,16], have also evaluated student's behavior in synchronous online lectures, showing successful patterns.

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Attendance and quality assurance of these synchronous courses are essential to support higher education systems in responding to the emerging needs and challenges, while ensuring student qualifications and experience remain at the forefront of institutional missions [3]. Each university therefore includes periodic evaluation processes aimed to improve the education quality and increase attendance. These processes are often part of a (formal) quality assurance model based on internal procedures and generally subject to an external check from third-party agencies. Responding to diversity and growing expectations for higher education is leading to a shift in its provision, which requires a student-centered approach, flexible learning paths, and prompt refining of the courses [1].

Open Issues. Monitoring the attendance and quality of instruction is however an important yet challenging task. Existing processes tend to survey students' opinions via questionnaires at the end of the semester. Subsequently, didactic managers analyze the provided answers, and finally discuss them with individual instructors and the board of instructors of the involved degree program. Since this evaluation process is performed once the semester is finished, (the board of) instructors receive feedback some months after the courses are ended. Unfortunately, this time gap does not allow to take timely interventions during the current semester, but just right before starting the next course iteration. Ideally, these procedures should instead provide insights promptly, to support instructors in refining their teaching and, as a result, get students to learn effectively.

To not leave students of the current iteration behind, monitoring the course quality and attendance along the semester is essential. Nevertheless, asking to students to fill presence forms or quality questionnaires very often along the semester and to didactic managers (and instructors) to analyze them is time-consuming and unscalable. To address this limitation, recent methods have injected machine learning into course quality and attendance prediction. Emerging works [4,9,15] made first steps in this direction. For instance, one of them has modeled student behavior through attendance records of a large university [2]. However, they all focused on a narrow set of courses and relied on video interaction logs not available for synchronous courses. Synchronous course attendance and quality prediction has by no means been researched exhaustively.

Our Contribution. In this paper, under an online real-time classroom scenario, we investigate whether student attendance patterns until a certain lecture are predictive of the quality and the future attendance of synchronous courses. For this purpose, we first pre-processed both (i) the student participation logs for all the courses provided by a public university and (ii) the quality indicators left by students for those courses in the final questionnaires. Then, we extracted predictive features from the behavioral patterns pertaining to student participation and applied a machine-learning approach to predict the future attendance and the quality indicators from those features. Finally, we discussed our results and the main implications for course attendance and quality prediction.

2 Methodology

Our goal is to analyze the predictive power of machine-learning models for early course attendance and quality prediction, based on patterns extracted from past attendance logs. To this end, we implemented a supervised classification pipeline. We first collected student participation logs and extracted relevant features that model student participation. We finally trained and evaluated classifiers on attendance and quality indicators separately. Figure 1 depicts our framework.

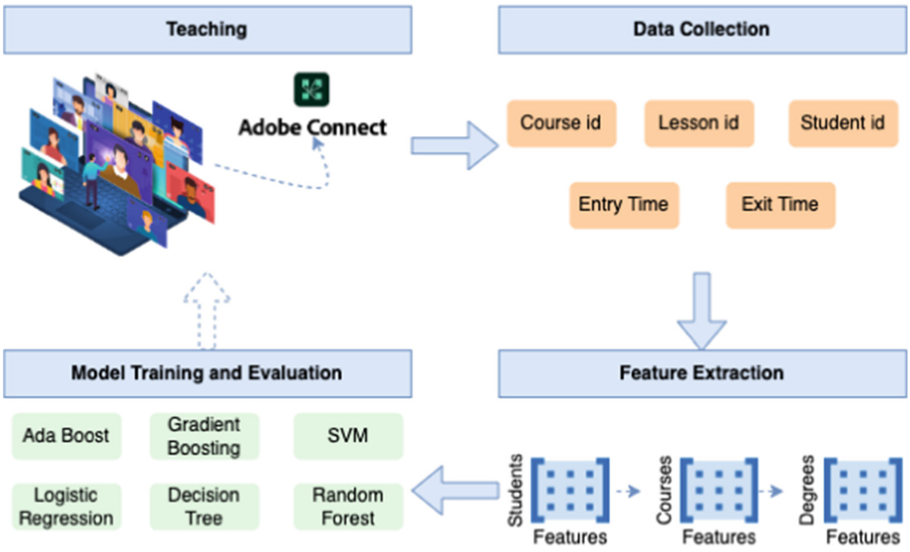

Fig. 1. Courses in our context were delivered on Adobe Connect, which is an online platform for enabling synchronous learning. We collected student participation logs, including the course id, the lesson id, the student id, and the time the student entered and left the lecture. We then extracted a range of relevant features from these attendance records. Finally, we trained and evaluated classifiers for future course attendance and quality prediction.

2.1 Data Collection

Our study considers student attendance logs coming from a large public university with more than 25,000 students, 6 faculties, 89° programs, and 1,230 courses[1]. Each lecture of a course has been delivered synchronously in a virtual room. Students enrolled in a course could login to the virtual room and enter the virtual room associated to the lecture they were required to attend. For each lecture, the date and time of entry and exit of students from the virtual room have been tracked for an entire semester. A raw log record included the course

[1] All data was collected in a completely anonymous way and the study was approved by the responsible institutional review board prior to our data processing.

id, the lecture id, the student id, the entry timestamp, and the exit timestamp[2]. A detailed overview of the data is provided in Table 1.

Table 1. Schema of the data structure and fields leveraged in this study.

Entity	List of Attributes	#Records
Degree	Degree id, level (BSc, MSc)	89
Course	Course id, year, degree id	1,230
Lessons	Lesson id, teaching id, date, start time, end time	13,000
Accesses	Lesson id, student id, access time, exit time	525,000
Students	Student id, year of attendance, course id	25,000
Indicators	Teaching id, question category, question criterion, overall grade	3,500

Table 2. Levels scale for each considered quality indicator.

Level	Description
AA	Very positive
A	Overall positive, situation to be consolidated
B	Sufficiently positive, situation with room for improvement
C	Slightly positive, situation with considerable room for improvement
D	Slightly critical, attention required
DD	Critical, intervention is required
E	Very critical, intervention is particularly required
F	Extremely critical, structural intervention required

We also collected the quality indicators of all degree programs provided in that semester, computed based on the students' answers to the university questionnaire. Due to privacy reasons, the quality indicators computed for each individual course in a degree program could not be accessed. Our study therefore focused on quality prediction at the degree program level. For each degree program, 14 course quality indicators were computed, including pre-course (preliminary knowledge, study workload, course material, examination method, content novelty), in-course (punctuality, motivation, clarity, tutoring activities, syllabus coherence, availability, lecture interest), and post-course (overall satisfaction, online satisfaction) indicators. Each indicator ranged between AA and F, as per the scale described in Table 2. In our preliminary experiments, the indicator values were binarized, assigning a label 0 for that indicator to that degree program if the indicator was below the average indicator value across programs, 1 otherwise.

[2] Note that these logs can be collected also in case of in-presence face-to-face lectures.

2.2 Feature Extraction

Prior studies have shown a strong relationship between academic achievement and students' behavioral aspects [5,12,13]. Notable learning dimensions include persistence in learning, ability to plan study time, awareness and control, and carefully examining material. Accordingly, various features sets have been presented in the literature, such as in [11]. However, these studies were conducted on asynchronous courses based on pre-recorded micro learning videos. In our study in this paper, we made the attempt of deriving features with the same rationale, constrained to the available logs and the synchronous scenarios.

Table 3. Features extracted from attendance logs in our study.

Dimension	Feature Name	Description
Student level	Late	The student logged in after class time
	Hasty	The student logged out earlier than the average time of the exits
Lecture level	Attendance rate	Percentage of the lesson attended
	Avg jump	Average of "jumps" related to the access time between one lesson and the previous one
	Average time access	The average time spent per lesson
	Standard deviation	The standard deviation of the time spent in each lesson
	Max and min time	The highest and lowest access time of a student
	Daily lessons	Number of lessons attended on the same day
	Lessons per day	Number of daily lessons taken by a student over time using Kurtosis and Skewness
	Lesson time	Average time of attended lessons
Course level	Teaching participation	Measurement of the level of participation through Kurtosis and Skewness
	Attended courses	The number of courses attended by the student in the same period

For each course, we extracted a range of features, presented in Table 3. Course-level features include course properties that might influence the perceived quality of the student (the time of the day the course lectures were delivered, the kurtosis and skewness of the distribution of the number of students attending the lectures so far). Lecture-level features model the student participation behavior across lectures (the average time the students spent in that lecture, the average lecture proportion followed by the student, the number of students who attended that lecture). Student-level features are related to individual student characteristics that can influence their attendance (the number of courses the student is attending, whether the student tends to join late or leave early a lecture). All these features can be extracted from the raw participation logs. Given that we had access to quality indicators at a degree program level only, in case of course quality indicator prediction, we averaged the features of all students and lectures (ranging between 12 and more than 15) in a course and then of courses belonging to a degree program, to obtain a single feature vector per degree program.

2.3 Models Creation

A wide range of machine-learning models have been analyzed so far in the educational literature, e.g., for student success prediction [8]. To align with prior work, though our study is focused on another prediction task, we considered models that have reported a high accuracy in education-related scenarios. We specifically included the following models:

- **Ada Boost Classifier.** It is an adaptive classifier, which can be used in conjunction with many other types of learning algorithms to improve performance. Usually, AdaBoost is used for binary classification, although it can be generalized to multiple classes or limited ranges on the real number line.
- **Gradient Boosting Classifier.** It combines the AdaBoost method with minimization. The goal of this classifier is to minimize the difference between the actual class value of the training example and the expected class value.
- **Support Vector Machines.** It is a classification technique conceived for binary classification problems, but which can also be extended to multi class problems by dividing the problem into a series of binary sub-problems.
- **Logistic Regression Classifier.** It uses a logistic function to model the dependent variable. The dependent variable is dichotomous in nature, so this technique can only be used with binary data.
- **Decision Tree Classifier.** This is a technique that allows to represent a set of classification rules of type *if - then* by means of a tree.
- **Random Forest Classifier.** This technique combines single trees into *forests*, according to the *ensemble* paradigm, minimizing the overfitting of the training set with respect to decision trees.

When not explicitly stated, for conciseness, we will report performance only for the Random Forest Classifier, which has often returned a good compromise between accuracy of the prediction and interpretability of the result.

2.4 Model Evaluation

For each course/degree and model, we applied a nested stratified (i.e., dividing the folds by course/degree) 10-fold cross validation. The same folds were used for all experiments across models, and we optimized the hyper-parameters via grid search. In each iteration, we ran an inner 10-fold cross-validation on the training set in that iteration, and selected the combination of hyper-parameter values yielding the highest accuracy on the inner cross-validation. For each model, the Area under the ROC Curve (AUC) was computed on the training and validation sets to check validity and on the test set to assess model generalizability. Note that we trained models by lectures: the model for lecture l of a given course was trained on features extracted from data collected up to lecture l.

3 Experimental Results

Our study aimed to investigate course attendance and quality prediction from attendance records. The models, the evaluation results, and the source code are available for replication on Github. Despite our methodology is flexible enough for being adapted to analyze several perspectives, we focused on the following three research questions:

- **RQ1.** Can we accurately and early predict course quality indicators given by students to a degree program?
- **RQ2.** To what extent are our extracted features and models predictive of whether a student will attend the next lecture of a course?
- **RQ3.** Can we early predict whether a student will attend a certain amount of the subsequent lectures?

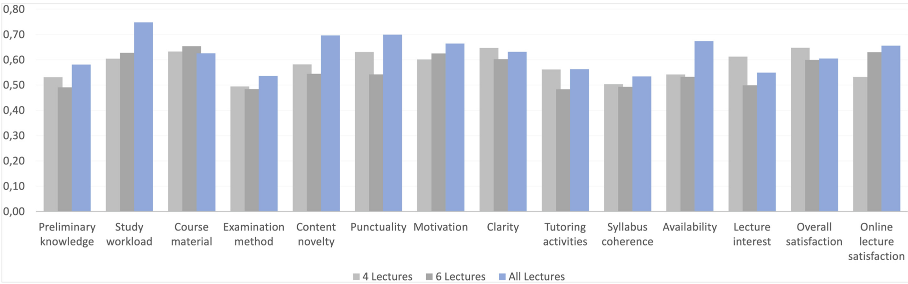

Fig. 2. Models performance (AUC) on the course quality prediction task (RQ1).

3.1 Course Quality Prediction (RQ1)

In a first analysis, we investigated whether the student participation features are predictive of the aggregated quality indicators of a degree program early in the course. For each indicator, Fig. 2 reports the AUC obtained with the Random Forest Classifier trained on attendance records until the fourth and the sixth lecture (gray bars) and the model trained on all the lectures (blue bars).

When the full data was available, the AUC ranged between 52% (for examination method) and 76% (for study workload). The overall satisfaction (and also the one related to the online activities) could be predicted reasonably well, especially those online. In more detail, indicators that could be predicted reasonably well included a range of content-related indicators, such as study workload, course material, and clarity pertaining to the course content itself, and a range of instructor-related indicators, such as punctuality, motivation, and availability.

For early prediction, six out of the nine indicators, which were accurately predicted with the full course data, can be predicted reasonably well even after six lectures, so very early in the course. For several courses, six lectures mean two or three weeks of course. Content novelty, punctuality, and availability can be instead predicted with a reasonably good accuracy only with the full course data. Models trained on the other quality indicators did not reach a good performance. Interestingly, the lecture interest was better predicted after four lectures than after the full course. We conjecture that the attendance records did not convey enough information about students' behavior to predict indicators that might be so complex. Nevertheless, learning monitoring and tracking in synchronous courses is limited, and future work should include fine-grained logs of activities and interactions during a lecture as well.

Findings RQ1. *Not all indicators could be therefore predicted with a reasonably good accuracy of at least 63-65%, even when the full data was available. Those that were predictable, even after six lectures, resulted in model performance close to that of models trained on all lectures.*

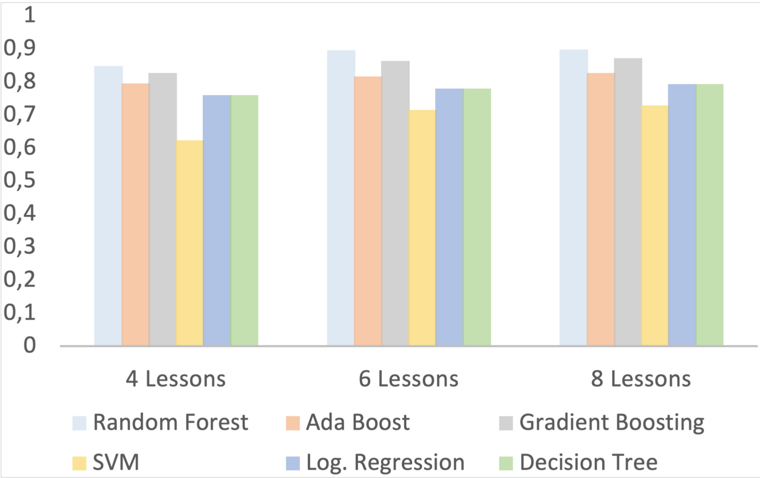

Fig. 3. Models performance (AUC) on the next lesson participation task (RQ2).

3.2 Predicting Attendance to the Next Lecture (RQ2)

In a second analysis, we were interested in investigating whether, given the behavior of a student up to the a certain lecture, we could predict whether they will access to the next lecture. Figure 3 collects the AUC scores for all models with features extracted until the forth, sixth, and eighth lecture.

It can be observed that the Random Forest Classifier had the best performance. In particular, after only four lectures, this classifier reached an AUC of 84%. The AUC score increased to 89% after 6 and 8 lessons. The second most accurate model was represented by the Gradient Boosting Classifier, with an

AUC of 85% after 4 and 6 lectures and 87% after 8 lectures. It is worth noticing that the gap in performance with respect to the Random Forest Classifier was not substantial. On the other hand, Support Vector Machines was the worst performing model. In particular, for this model, we reported an AUC ranging between 56% and 58%, after 4, 6, and 8 lectures respectively. Therefore, except for this model, all the other models were able to provide reasonably accurate predictions regarding whether a student will attend the next lecture of the course. Though performance was high even after just 4 lectures, models trained after 6 and 8 lectures reported a more stable behavior.

Findings RQ2. *Except for Support Vector Machines, all models were able to provide reasonably accurate predictions regarding student attendance to the next course lecture. The Random Forest Classifier was proven to be the most accurate model in this study.*

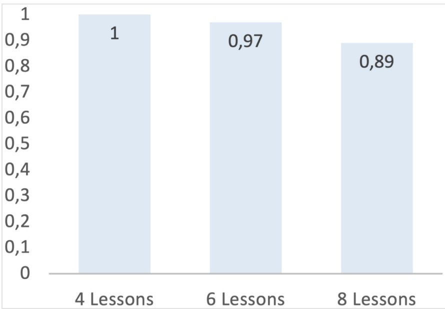

Fig. 4. Percentage of students for whom the course attendance requirement prediction was not trivial (RQ3).

3.3 Predicting Attendance to a Course Lectures Percentage (RQ3)

In a third analysis, we were interested in investigating whether it is possible to early predict by means of a machine-learning model whether a student will meet the course attendance requirement usually asked in a university. In many universities, to take the final exam, students are indeed asked to attend at least a certain percentage of the course. In our experiments, we considered a threshold of attendance to at least 70% of course lectures.

Before training models for this task, we performed an exploratory analysis to understand for how many students, after a few lectures of the course, it would be still important to perform such prediction task. In fact, up to a certain lecture of a course, there might be students who are absent for a number of lessons and it would be already evident that they will not be able to reach the minimum attendance threshold. For instance, in a 10-lecture course, if a student missed the first four lectures, predicting that student will not meet the course attendance requirement would be trivial. For this reason, those students were excluded from our processing. Figure 4 shows the percentage of students for whom it was not trivial to predict whether they will participate in at least 70% of the lectures, under the above definition. In the plot, it can be observed that, after 4 lectures, we still have the 100% of students. However, after 6 lessons, there was a decrease of 3% and after 8 lectures, it was reached a student percentage of 89%.

Given those students, we trained our models and reported their performance in terms of AUC in Fig. 5. For each model, we observed very interesting yet different performance patterns. For the Random Forest Classifier, we noticed that there was a very little increase in performance along lectures. Indeed, the AUC scores reported for this model were stable after 4, 6, and 8 lectures. From the fourth lecture, we already reported a good predictive ability, and the gain was lower than 0.01% in the subsequent settings. Specifically, after 4 lectures, the AUC reached a value of 89%. The AUC score increased after 6 (90%) and 8 lectures (91%). The Random Forest can be considered a good model for this case study.

Ada Boost's performance remained stable between 75% and 77% for all the settings. Despite of being reasonably high, the AUC scores reported by this model were lower than those observed for the Random Forest Classifier. The Gradient Boosting variant instead performed better after 4, 6, and 8 lectures. In particular, we measured an AUC score for this model ranging between 83% and 84%. It is worth noticing that Gradient Boosting in more efficient than Random Forest an, therefore, should be preferred in case of large datasets or low computational resources settings.

As for the previous prediction tasks, the Support Vector Machines reported the lowest AUC performance. In fact, the AUC scores for this model were between 58% and 62%. Given their closeness to the AUC value of 50%, which represents a classifier that yields random prediction, this model should not be used for the considered prediction task. Logistic Regression and Decision Trees were characterized by very similar yet low performance estimates in terms of AUC. Their values ranged between 67% and 72%.

Findings RQ3. *Not all models were able to early and accurately predict whether a student will meet the course attendance requirement (i.e., participating in at least 70% of the course lectures). Random Forest Classifier reported again the best performance estimates in terms of AUC, followed by Gradient Boosting, which should be preferred in case efficiency is important. The other classifiers did not report reasonably high performance estimates.*

Fig. 5. Performance in terms of AUC for the course requirement task (RQ3).

4 Discussion and Conclusions

In this work, we combined multiple dimensions of student participation to obtain accurate (early) predictions of course quality. Unlike current manual practices based on questionnaires, we applied a fully-automatic and transparent machine-learning pipeline along the whole course catalog of a public university, covering different topics, instructors, course lengths, and study levels. Our results showed that student participation can be used to predict certain quality indicators and future student attendance in advance, scalably and transparently.

The values of the model evaluation metrics for the considered tasks allow us to confirm the predictive power of student attendance behavior and patterns. In particular, with the access data collected from the first 4 lectures, we are able to predict with good accuracy a good range of quality indicators, the access to the next lecture, and the attendance of at least 70% of the lectures. These data can be used by the instructor to have more evidence about their own course delivering and take action to actively improve students' academic situation from the very first lessons. For instance, the instructor could plan in advance certain activities for the next lecture based on the number of students who are expected to attend it. To conclude, our results show that our models can support instructors in deriving actions to mitigate low class participation and course quality barriers. Our models are potentially applicable to both online distance education and face-to-face education, where the university might have a digital entry and exit system in place (e.g., through access badges).

Future work will embrace our findings to assess quality prediction at course level (our predictions were at degree program level due to privacy constraints) on other contexts (e.g., other universities), and with other features and predictive models. For example, if the system predicts low class participation for a significant number of students attending a certain course or enrolled in a specific degree program, there are many possible early dropouts, then the organization of specific support services (e.g., supplementary courses, personalized guidance) could be envisaged.

Other important next steps include user studies with both students and instructors to get real-world evidence of the effectiveness of the system. The results of this analysis could direct us to improve the implementation of the system, for example by using different and more robust strategies. We foresee that in an integrated system, where data is collected systematically and consistently, there are wide opportunities to create a well-established tool. We also plan to analyze predictiveness across faculties, study level, and teaching modalities, and embed models predictions into dashboards.

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Learning Analytics to Predict Students' Social-Relational Skills in an Online University Course

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Abstract. Students' successful and timely University completion has been one of the biggest challenges in higher education. In telematic environments it has already been amply demonstrated that greater participation by students in course activities is associated with better academic results [1]. The present study takes place within the Telematic University of Studies (IUL) and aims to verify the association between some variables related to the educational success of students, other than grades to exams, and the number of synchronous and asynchronous activities carried out within the Learning Management System (LMS) platform dedicated to the course as well as with other demographic variables such as gender and age. Since educational success is a multidimensional concept, it is important to study it from all its points of view [2]. This study therefore, aims to predict the social-relational skills related to the educational success of the students, through the behaviour of the students on the LMS platform. To find this, the association between students' behaviours on the LMS platform, some demographic variables, and students' social-relational skills used as a proxy for educational success was studied through a multiple linear regression model.

Keywords: Learning Analytics · Students' Success · Online Higher Education

1 Introduction

Focused and accurate information can help to build models to prevent school drop-out and improve the educational success of students [3]. Factors determining academic success can relate to aspects of teaching and the educational model as well as to student characteristics. Study skills, motivation and self-efficacy can affect time management skills and educational success itself [4].

In the literature, there are several uses of multiple linear regression models [5] and logistic regression models [6] to predict the academic performances of students in a university course or the probability of dropping out by observing their behaviours in online learning environments. Indeed, it has already been shown that as the participation of students in online course platforms increases, exam grades tend to increase on average and the probability of dropping out tends to decrease on average [1, 5, 6].

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The study of students' behaviours is particularly favored in virtual contexts. In these, in fact, a whole series of data from platform tracking can be collected. LMS is the online platform that students access to follow the lessons, download the teaching material and to communicate with each other and with the teacher. It automatically collects a large amount of data. These data are called logfiles and they can be used to understand learning behaviours and to predict students' academic results [7].

The present study takes place within the Telematics University of Studies (IUL). Among the many opensource platforms available, IUL has chosen to use Moodle. Because of its characteristics [8], Moodle is one of the most widely used e-learning platforms in the university sector, widely disseminated, it offers excellent technical support, and it offers users the possibility of customizing its offerings. The aim of this study is to understand which factors can predict the educational success of students within an online university setting. This prediction will be conducted using a multiple regression model. The independent variables in the model will be the data obtained from the extraction of log files from the Moodle platform, gender and age; the dependent variables will be the social-relational skills related to educational success.

2 LA for Predicting Students' Success

Learning Analytics is the measurement, collection, analysis and reopening of data about learners and their contexts, for purposes of understanding and optimizing learning and environments in which it occurs [7]. From a statistical point of view Learning Analytics can be used to investigate the relationship between independent variables (influencing factors) and dependent variables (students' academic results). Being able to predict student performance by analyzing their behaviours on the LMS platform can allow teachers to intervene promptly and with personalized feedback to help students at risk of dropping out [9].

Some of the most representative methods of Learning Analytics based on a comprehensive literature review will be presented.

Kotsiantis et al. (2004) in the field of distance learning education, proposed a model that uses six different machine learning techniques; they found that demographic variables are good predictors for students' performances [10].

Shalem et al. (2014) found that students' demographic characteristics and personality traits correlate with each other and have a statistically significant impact on students' academic performance in web-based education. To study this relationship a probabilistic graphical model was implemented [11].

Soule (2017) used a multiple logistic regression model to determine which variables mostly affect the educational success of students of four Southern Illinois University Carbondale courses (three mathematics courses and one biology course). He found that in all four courses "Test" and "Homework" scores are better predictors than "Pretest" score and "Attendance" for the probability of getting a sufficient grade on the final exam [12].

Oyerinde and Chia (2017) used a multiple linear regression model to predict students' academic performance [13].

Luppi and Benini (2017) have shown on a sample of students of the nursing course that the socio-cultural factors of the students, detected through the "Learning Strategies

Questionnaire", are crucial to determine the working attitudes of the students and are essential to evaluate their learning experience [14].

Garg (2018) used classification methods to predict the academic performances of college students based on high school results and found a positive and significant association between the two [15].

Ndoye et al. (2020) used a multiple linear regression model and T-Tests to predict and compare college students' academic success. As predictors for the academic success, they used the scores of the dimensions obtained through the Academic Success Inventory for College Students (ASICS), which is a 7-point scale instrument of 50 questions divided into 10 subscales [16].

All these studies therefore relate students' behaviours with academic performance measured from an objective point of view: exam grades. The association found between the active participation of students and their exam grades has always been positive, both in online and traditional universities, and also in different courses of study.

However, since educational success is a multidimensional concept [17] and cannot be evaluated only through exam grades, there is a need to find out if other transversal variables, identified by social relational skills, have an association with the active participation of students and with some of their demographic characteristics. This will therefore be the purpose of this study.

3 Online Collaboration and Soft Skills Development

Transversal competencies concern the different knowledge of the disciplines, but also the multiple skills that the professions require; a set of personal qualities (soft/character skills), which can be cultivated and improved through training, including at university level [18]. The university becomes a privileged place where these aspects can be cultivated, through the promotion of autonomous research, discussion, and reworking of meanings [18]. To promote students' transversal competences through collaboration, one of the possibilities is the development of interactive and collaborative activities, with the aim of fostering and observing the development of networked communities. Indeed, it is hypothesized that the introduction of social activities within a university online course, and a greater emphasis on collaborative and group learning, may have positive effects both in terms of student engagement and the development of meaningful learning and transversal competences. The university provides a learning environment designed to promote a networked approach to knowledge and to foster the construction of knowledge through collaboration and sharing between participants [19].

The research adopted the Community of Inquiry (CoI) model [20] as a framework for structuring the learning environment, collaborative activities and the analysis of results. The pedagogical roots refer to a constructivist pedagogical perspective and, in particular, social constructivism, which emphasizes the fundamental role of interaction among students and between students and teachers for the development of high-level cognitive and metacognitive processes, motivation to learn, self-esteem and the growth of a sense of social belonging. During and in the aftermath of the Covid-19 pandemic, the telematic universities represented a response to the need for flexibility and continuity of training determined by the new socio-economic reality; but, at the same time, they represented a particularly fertile context for experimenting with innovative teaching strategies, exploiting the potential offered by the new technologies, as well as a privileged platform for reflecting on the limits and criticalities that these same technologies have shown and show, especially when they are used to wearily repeat transmission models borrowed from face-to-face training.

4 Methodology

4.1 Participants

To study students' behaviours and educational success, the synchronous and asynchronous teaching activities carried out by the students of the first year of the academic year 2020/2021 in the teaching of 'General Psychology' of the degree course in Human Resources Psychological Sciences and Techniques (N = 46) were analyzed. During the course, the students have completed the Turning Potentials into Capacities (TPC) questionnaire [21], of which, five dimensions obtained through some of the answers to this questionnaire were then used as dependent variables in statistical analyses.

Gender and age were considered as independent demographic variables. The group consists of 73,9% of female students and 26,1% of male students. Being an online university course, the age distribution of students is different from that of standard university courses and has a strong variability. The average age is 36,1; the median age is 34 and the standard deviation of the age is 10,5.

4.2 Tools

To make the most of IUL's social construction of knowledge model, the use of a standardized test was introduced to measure students' social-relational competences as characteristics capable of influencing educational success. The TPC [21] is a multidimensional questionnaire that explores dimensions such as agenticity, i.e. the tendency to play an active role in contexts; sociability, which includes aspects such as pro-sociality and friendliness, trust; personal organization, which concerns knowing how to manage oneself to achieve goals, thus in relation to commitment, coherence with roles in social contexts; and openness, i.e. propensity for change and innovation. It is a self-report questionnaire consisting of 144 items, with a 7-step response scale (from "completely disagree" to "completely in agreement"). The scores of the various items are then combined and standardized with each other to obtain the scores in a range from 0 to 100 points at the various dimensions and subdimensions.

The five dimensions of TPC used as dependent variables in this study are: The Prosociality i.e. The Competence to foster, without the search for external, extrinsic or material rewards, other objectively positive persons, groups or social ends. The Accuracy i.e. The ability to carefully and accurately perform a job or an activity. The Reliability i.e. The quality of being considered trustworthy. The Assertiveness i.e. The ability to express their emotions and opinions clearly and effectively without offending or attacking the interlocutor. The Commitment i.e. The ability to employ all one's goodwill in carrying out an activity or a job [21].

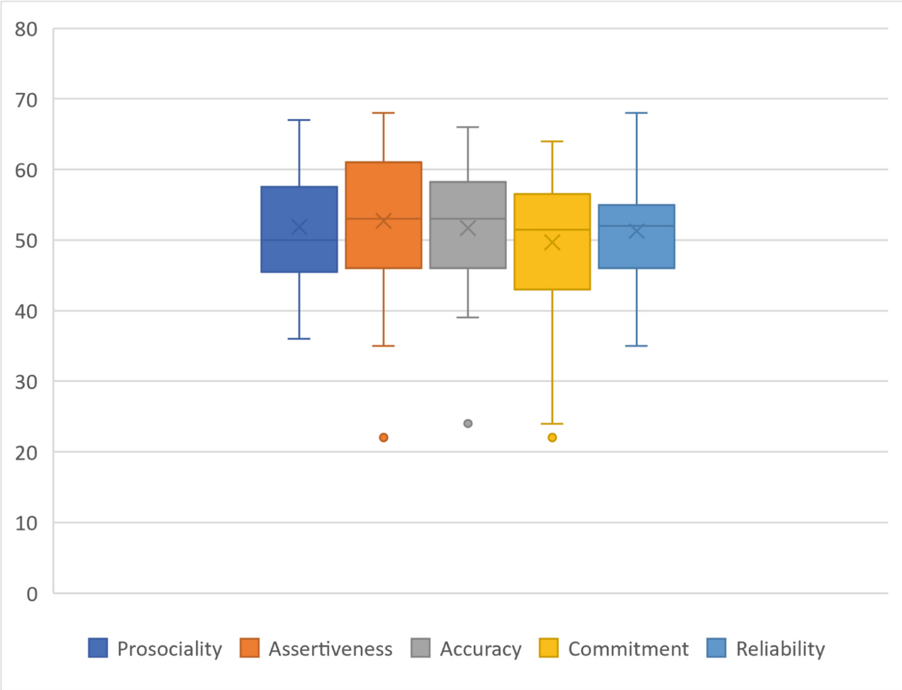

Fig. 1. Boxplots for the five TPC dimensions

The boxplots in Fig. 1 help to evaluate the distribution and trends of the scores to the five dimensions considered. It is noted that the scores of the five dimensions all have similar distributions with average and median slightly above 50 and a first and third quartile around 40 and 60 points. The exception is assertiveness which has a third quartile slightly above 60 points.

4.3 Data Analysis Procedures

Asynchronous activities mean all activities carried out on the Moodle online platform that do not involve simultaneous interaction between students and teacher, for example, viewing or downloading teaching materials, posting a speech in the educational forum and answering a questionnaire. For synchronous activities it is intended to participate in live lessons with the teacher. Information on the number of activities carried out by students on Moodle is obtained through the collection of the log files of the course.

The final dataset that was used for statistical analysis is the result of the combination of three different datasets joined through data link operations. From the answers of the TPC questionnaire the dataset was obtained with the scores of the five dimensions considered as dependent variables. From the "log" section of Moodle the dataset of the log files containing the number of synchronous and asynchronous activities carried out by the students on the platform was obtained. The dataset containing the demographic variables of the students was obtained from GOMP, a portal that acts as a student registry.

This research is meant to predict students' social-relational skills using a Multiple Linear Regression Model. Multiple Linear Regression is used to find the relationship between a dependent variable and two or more independent variables. The theoretical assumption is that, for every one unit change in the independent variable, there is a consistent and uniform change in the dependent variable. The Multiple Regression Model in matrix form takes the following form:

$$y = X\beta + u \tag{1}$$

where:

y is the vector (n x 1) of observations on the dependent

variable. X is the matrix (n x k) of observations on independent

variables. β is the vector (k x 1) of the regression coefficients.

u is the vector (n x 1) of stochastic errors.

To select relevant variables that could predict performances effectively, a list of potential attributes was identified from review of literature [1, 10, 11], where certain variables (number of synchronous activities, number of asynchronous activities, gender and age) were found to be good predictors for students' academic performances.

This study aims to verify if these same variables are good predictors even for the social-relational skills of the students identified by the five dimensions of the TPC questionnaire (Prosociality, Accuracy, Reliability, Assertiveness, Commitment).

For the analyses the statistical software Stata 14.1 was used. Five multiple linear regression models were then constructed, one for each dimension of the TPC questionnaire taking the following model as a reference:

$$y = \beta_0 + X_1\beta_1 + X_2\beta_2 + X_3\beta_3 + X_4\beta_4 \tag{2}$$

where:

y is the dependent variable; the standardized scores to each dimension of the TPC questionnaire.

X_1 is the number of synchronous activities carried out by students on Moodle. X_2 is the number of asynchronous activities carried out by students on Moodle.

X_3 is the dichotomous variable (0;1) that identifies gender: 0 for females and 1 for males.

X_4 is the age in completed years.

β_0 is the constant value.

β_1, β_2, β_3, β_4 are the attributes associated with the variables.

Hypothesis Testing was used with the Null hypothesis, H_0, being that there is no relationship between the predictors (Number of synchronous and asynchronous activities, gender and age) and the predicted (Standardized scores to the TPC dimensions) variables. The Alternate hypothesis, H_1, therefore is that to a reasonable level of significance, in this case 10%, there is a relationship between the predictors and the predicted.

5 Results

To introduce the context of the analyses, a Pearson correlation analysis was carried out on the five dimensions of the TPC questionnaire (Table 1).

Table 1. Pearson correlation analysis for the five TPC dimensions

	Prosociality	Assertiveness	Accuracy	Commitment
Assertiveness	0,458***			
Accuracy	0,316**	0,195		
Commitment	0,374**	0,609***	0,175	
Reliability	0,307**	0,446***	0,440***	0,577***

All dimensions of the TPC are positively correlated, five of the ten relationships are highly significant *** (P-value $<$ 0,01) and three are significant ** (P-value $<$ 0,05). The following tables summarize the results of the five multiple regression models.

Table 2. Regression model overview for Prosociality

	Dependent variable: Standardized score for Prosociality				
Prob > F = 0,000		F (4,41) = 8,06		n = 46	
Covariates	Coefficients	Standard Error	t	Confidence Interval 95%	
Synchronous activities	4,722	0,869	5,43***	2,966	6,478
Asynchronous activities	−0,001	0,003	−0,25	−0,007	0,005
Gender	1,165	2,304	0,51	−3,489	5,820
Age	0,002	0,096	0,02	−0,191	0,196

The model in Table 2 shows that the number of synchronous activities is a good predictor for students' prosociality and that these two variables are positively ($\beta_1 =$ 4,722) and highly significantly associated (P-value $<$ 0,01).

Table 3. Regression model overview for Assertiveness

	Dependent variable: Standardized score for Assertiveness				
Prob > F = 0,000		F (4,41) = 7,91		n = 46	
Covariates	Coefficients	Standard Error	t	Confidence Interval 95%	
Synchronous activities	3,999	1,020	3,92***	1,938	6,058
Asynchronous activities	−0,001	0,004	−0,23	−0,008	0,007
Gender	6,286	2,704	2,32**	0,825	11,746
Age	0,251	0,112	2,23**	0,024	0,479

The model in Table 3 shows that the number of synchronous activities, gender and age are good predictors for students' assertiveness. Number of synchronous activities and assertiveness are positively ($\beta_1 = 3{,}999$) and highly significantly associated (P-value $< 0{,}01$). Gender and assertiveness are positively ($\beta_3 = 6{,}286$) and significantly associated (P-value $< 0{,}05$). Since the gender variable takes on a value of 1 for males, the score of males is on average 6,286 higher than that of females. Age and assertiveness are positively ($\beta_4 = 0{,}251$) and significantly associated (P-value $< 0{,}05$).

Table 4. Regression model overview for Accuracy

	Dependent variable: Standardized score for Accuracy				
Prob > F = 0,153		F (4,41) = 1,77		n = 46	
Covariates	Coefficients	Standard Error	t	Confidence Interval 95%	
Synchronous activities	1,873	1,088	1,72*	-0,324	4,070
Asynchronous activities	−0,001	0,004	−0,16	−0,008	0,007
Gender	2,291	2,884	0,79	3,533	8,116
Age	−0,195	0,120	−1,62	−0,437	0,047

The model in Table 4 shows that the number of synchronous activities is a good predictor for students' accuracy and that these two variables are positively ($\beta_1 = 1{,}873$) and significantly associated (P-value $< 0{,}10$).

Table 5. Regression model overview for Commitment

	Dependent variable: Standardized score for Commitment				
Prob > F = 0,153		F (4,41) = 3,77		n = 46	
Covariates	Coefficients	Standard Error	t	Confidence Interval 95%	
Synchronous activities	4,018	1,150	3,49***	1,695	6,341
Asynchronous activities	−0,003	0,004	−0,93	−0,012	0,005
Gender	1,217	3,050	0,40	−4,941	7,375
Age	0,145	0,127	1,15	−0,111	0,402

The model in Table 5 shows that the number of synchronous activities is a good predictor for students' commitment and that these two variables are positively ($\beta_1 = 4{,}018$) and highly significantly associated (P-value $< 0{,}01$).

The model in Table 6 shows that the number of synchronous activities is a good predictor for students' commitment and that these two variables are positively ($\beta_1 = 2{,}893$) and highly significantly associated (P-value $< 0{,}01$).

Table 6. Regression model overview for Reliability

	Dependent variable: Standardized score for Reliability				
Prob > F = 0,039		F (4,41) = 2,78		n = 46	
Covariates	Coefficients	Standard Error	t	Confidence Interval 95%	
Synchronous activities	2,893	0,984	2,94***	0,905	4,881
Asynchronous activities	−0,003	0,004	−0,79	−0,010	0,004
Gender	0,990	2,609	0,38	−4,279	6,259
Age	−0,065	0,109	−0,60	−0,285	0,154

6 Discussion

The strong positive association between synchronous activities and high scores to the dimensions of educational success confirms the validity of a teaching model based on the Community Of Inquiry (COI) adopted by IUL that places the interaction between students and teachers at the center of the learning process [22].

This study has achieved the goal of implementing a model capable of predicting students' social skills through the number of synchronous activities. Since the effect of demographic variables, (gender and age), has not been significant except for assertiveness, in future studies it would be interesting to verify the effect of the degree course evaluated through multilevel models [23].

From a practical point of view, this study was not without difficulties. Although universities have a large amount of student data available, it is not always easy to find. In fact, data from three different sources were used for this study: the Moodle platform for students' log files, the students' registry "GOMP" for demographic variables and the TPC questionnaire for social-relational skills variable scores.

Not having the necessary data available quickly and easily is a problem that should not be underestimated. The fact that data referring to the same subjects are located in different databases causes difficulties of various kinds.

Those who need this data may not know where they are located or may not know how to find them. There may also be accessibility and permission issues with various databases. Finally, the large amount of time required to retrieve data could be an obstacle to efficient and timely analysis.

A further goal for the future may be to make data quickly and easily accessible to teachers, who can then obtain the information necessary to predict which students are in difficulty and take the necessary actions to help them.

7 Conclusions

The university can be the context in which to experiment innovative teaching methods [24], especially in online contexts where the learning environment lends itself to be particularly flexible. This study aims to consider a more holistic model for predicting educational success that takes into account both personal and learning environment information. In fact, an educational environment that fosters interactions also allows for a more productive exchange of feedback between students and faculty which in turn contributes to creating a better teaching experience for students and allows them to achieve better academic results from it.

A previous study [25] had found that a collaborative approach was a more "challenging" way for students to participate in an online course; however, perceptions of one's own digital competence appeared to be a likely factor in the choice of whether or not to interact in this type of context. On average, online collaborative activities were chosen by students who were younger and more familiar with online social interaction tools. Furthermore, students who had chosen the collaborative mode had, on the whole, spent more time on the course, in contrast to their peers who had not made the same choice. Time spent on study activities and motivation could be two variables influencing the development of transversal skills mediating the prediction of our model.

The results highlight how 'social presence', one of the dimensions of COI [20], can be an important aspect for the development of transversal competences useful for students' professionalism. Promoting collaboration and sharing in the performance of activities can in fact be useful for students in order to experiment in training contexts with skills and knowledge also required in the world of work.

In this respect, the European Council Recommendations [26], the international frameworks for the development of competences useful for 21st century life and the efforts made following the Bologna Process [27] and the WHO Guidelines [28], which identify general, transversal and transferable, a central core of education, including university education. There is therefore a need for a broad reflection on what are the expected results for this type of competence within the different areas and what space can be found within individual courses to promote this process.

Further investigation can be done to develop a model that can predict the development of transversal competences in online university contexts.

The study has limitations: since the data only came from one specific degree course, the model is not generalizable. However, it is interesting to have used a standardized test to assess transversal skills and to have used data from the LA to predict these skills. In the future, it will be possible to expand the sample and extend the observation to other courses.

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How Did University Students Adapt to the "New Normal" of Teaching and Learning During the Pandemic? Preliminary Indications from Semi-structured Interviews

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Abstract. The Covid-19 pandemic, and subsequent lockdown of traditional universities determined, among other things, the sudden switch from a mostly exclusive form of teaching and learning in presence to a full-online mode, which has been called emergency remote teaching (ERT). A number of studies reported that students experienced many difficulties during this period, due to personal, contextual, and technological factors. At the same time, students used their resources and coping strategies to build resilient behaviors and adapt to this unprecedented situation. An inter-university, mixed-method study investigated how those factors combined to shape university students pandemic experience and develop better university teacher training protocols. As a part of this project, a semi-structured interview protocol has been developed to investigate in-deep phenomena, observations, and insights that can help lead to the redefinition of teaching and learning practices. This study presents the protocol that has been developed and implemented to collect student experiences and feelings towards different aspects of their pandemic experience, with the aim of building teacher trainings programs able to adapt to students' coping strategies and foster their resilient behaviors. Preliminary results indicate that traditional universities might need to increase their push towards innovative instructional practices to face this challenge, while at the same time helping students build on the lessons learned during the pandemic period.

Keywords: Distance and blended learning · University students coping strategies · Teaching and learning innovation · Semi-structured interviews

1 Introduction

The spread of the Covid-19 pandemic in the early months of 2020 imposed lockdowns on universities, among other institutions, forcing a rapid transition into online teaching and learning. This event, where technology played an instrumental role as both the enabler of remote learning and in shaping teaching and learning practices, forever changed the

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landscape of higher education [1]. This difficult change had a profound impact on academic institutions, which had to warrant learning continuity and integrity of assessment practices [2, 3], as well as academic staff, including teachers, who reported significant alterations in work-life balance [4], but had arguably the most significant impact on the life and experience of university students.

There is little doubt that this passage proved very difficult for students, due to many reasons, including organizational, methodological, emotional, and psychological factors. On the one side, they had to adapt to a different mode of interacting with educational content, teachers, as well as their peers [5–8]. On the other, they had to do so within the context of fear and insecurity of a global pandemic, whose overall impact on the populations' well-being and mental health is only started to be appreciated [9, 10]. Several lines of investigation suggest that the ability to develop resilient resilient behaviors by students has been of great importance in shaping their experience and allowing them to adapt to the unprecedented challenges of the pandemic [11, 12]. Resilience is a multifaceted concept, which can be defined as the ability to quickly recover from negative events of different nature. It has been shown that different coping strategies can promote resilience in different contexts [13–15]; however, which coping strategies might have helped university students deal with the sudden switch to online learning and adaptation to a radically changed academic experience is still unclear.

Distance learning is not a novel concept: it existed for many years. However, the switch to online learning that happened during the pandemic was of a significantly different nature, which has been defined emergency remote teaching (ERT)[16]. This kind of online learning was defined by very limited time allowed for re-organization and characterized mostly by the adaptation of traditional forms of teaching and learning to online formats (i.e., synchronous frontal lessons). Reports on students' experience with ERT are somehow mixed; several studies report an overall positive reception of ERT [17] albeit some report a lower quality of learning [18], and several factors, including difficulties in managing workload and limited interaction with other students have been reported as having a negative impact [19]. In the Italian context, we previously reported, through the analysis of a questionnaire administered to more than 600 Italian university students in the spring of 2020, that undertaking online courses helped students cope with the difficulties and the stress of the unprecedented pandemic situation; furthermore, students' opinion of their experience with ERT was positively associated with several factors, including organization and quality of online content and interaction with teachers, whereas the need to reorganize their study habits was associated negatively [20]. However, this quantitative approach highlighted a strong heterogeneity in students' answers, likely reflecting the great variability of individual experiences, both in reacting to the pandemic situation and in adapting their learning habits and strategies to face the unprecedented challenge. Since this "acute" phase of ERT, however, what was an emergency became a "new normality": for an entire cohort of students, their entire experience of higher education mostly consisted in online or blended forms of teaching and learning. The present study has the aim of understanding how students adapted to this situation and which factors, linked to both online learning and personal aspects, such as the coping strategies used to develop resilient behaviors, helped them in the task.

The "Foster" Project

To understand how teaching and learning strategies during the pandemic influenced and fostered university students' resilience, a FISR-funded inter-university project, involving University of Bari, University of Foggia and, initially, University of Modena-Reggio Emilia[1], was launched to investigate the effects that emergency situations, such as the Covid-19 pandemic, can have on the cognitive and emotional states of university students, with the related effects in terms of achievement and educational success. The goal of the project is to use this knowledge, together with gathering and adapting the best international experiences on the subject, to develop better university teacher training protocols. To this aim, this mixed-methods project included both quantitative and qualitative methods of investigation. On the one side, we developed a student-directed questionnaire containing several standard scales investigating students' perceived loneliness (UCLA LS3 scale), coping strategies (Cope-NVI 25), and general health (GHQ-12), plus two custom scales, each composed of three items, related to quality of online learning ($\alpha = 0.77$) and resilience to online learning ($\alpha = 0.66$) [21]. The survey was diffused among students from the University of Foggia and the University of Bari, in order to understand the overall factors (socio-demographic, contextual, and technological) that played a significant role in the general health of university students; as well as to understand which coping practices were employed by students and had an effect on their perceived health. We found that expertise with digital devices had a positive effect on students perceived general health. Conversely, isolation and lack of relational connectedness had a negative effect on students' health. Furthermore, we found that coping strategies have different overall effects on student's health, with active coping strategies more likely to have a positive effect, consistent with the literature [13, 15, 21].

In parallel, we diffused a questionnaire aimed at teachers from the University of Foggia, to investigate their teaching and learning practices during the pandemic and identify their perceived needs in terms of required training and resources for online learning. Third, we developed the semi-structured interview protocol that is described in the present study. The triangulation of quantitative and in-depth qualitative analysis of student perceptions and experience during the pandemic is therefore the foundation for the rethinking of teaching and learning practices aimed at promoting students' well-being, resilience, and general health.

The next steps for the project include:

1. Through an analysis of the existing literature on the topic and the analysis of evidence obtained from university students and teachers, characterize the adaptive strategies adopted by teachers and students following the restrictions.

[1] Following the relocation of the Principal Investigator (PI) of the local area from the University of Modena and Reggio Emilia to the University of Foggia, the latter effectively had two research units with different PIs. Thus, the samples included in all studies of the project include only students and teachers from the University of Bari and the University of Foggia.

2. Design of an experimental training course for university teachers on the topics of innovative teaching strategies in face-to face and distance learning, suitable for developing students' resilience skills in normal and emergency situations.
3. Implementation of the training course aimed at an experimental sample of university teachers, identified based on the acquired results.

Following objective 4, the subsequent planned phases of the research include the comparison between an experimental group and a control group with pre and post-test assessment, and the follow-up assessment in six months.

2 Material and Methods

To understand the spectrum of different phenomena/observations/reflections that influenced and determined student's adaptation to this new form of academic life, we designed a semi-structured online one-on-one interview protocol (par. 3.1) addressed to a representative subset of students (par. 3.2), from the University of Foggia (UniFg). We chose to target exclusively students from the 2019–2020 cohort, that is, students whose university career included both a pre-pandemic, traditional university experience, as well as the sudden transition toward online learning during the quarantine and the post-pandemic and consequent adaptation to include different perspectives in the study (see par. 3.3). The aim of the study design was to obtain information from students through both quantitative and semi-quantitative linguistic analysis (par. 3.4) as well as qualitative content analysis (par.3.5).

2.1 Candidate Selection Criteria

We recruited potential interview candidates on a voluntary basis. To reach putative participants, a Google Form survey was diffused during courses as well as in informal student groups (WhatsApp and Telegram). Given the importance of demographic factors, including gender [22], wealth, and working status [23], on students' achievement and university experience, we chose to select interview candidates using a set of sociodemographic factors. Therefore, students had to indicate a set of characteristics, including:

- Genre
- Worker/non worker status
- Living in city/periphery
- Estimated family income (± 2000€/month)

The initial response to the survey was very positive, with 38 Students volunteering for the interviews as of December 2021. Based on sociodemographic criteria, 20 students where thus selected for interviews to guarantee a balanced sample. Unfortunately, since the time the survey was diffused to the time the interviews took place (mid-January 2022), several students retracted their availability for the interviews or stopped answering to communications. To reach a threshold of 15 interviews, which was considered instrumental to conduct a meaningful quantitative analysis, the selection criteria were thus lessened, focusing instead of availability.

2.2 Semi-structured Interview Protocol

The semi-structured interviews protocol consisted of two main sections: the first focused on the interviewee's experience with distance learning and the second most concerned with the student's strategies to deal with the emotional and psychological aspects of the pandemic: stress management and coping strategies, general happiness during and after the peak of the pandemic, and reflection on personal development and possible "silver linings" emerging from the pandemic (Table 1).

Following a pilot interview with an external subject, it was decided to start with questions on distance learning before proceeding with more sensible questions, as interviewer and interviewee had the time to grow reciprocal trust required to obtain quality answers.

Table 1. Structure of the interview

Thematic Areas	Questions
Biographic Area	Which course are you enrolled in? In what year did you start University? With whom did you live during the lockdown period? Which resources did you have at your disposal to follow lessons and study? Have your living conditions changed since then? (Do you live with the same people now?)
Distance learning	How would you describe your overall experience with distance learning? Which were the most common didactic modes (synchronous, asynchronous)? Which did you prefer and why? How do you feel your academic achievements change with respect to before the pandemic? What are the main difficulties you encountered? Which aspects of distance learning did you appreciate most? Which aspects of learning in presence did you miss? Which aspects of distance learning might have helped you face the challenges of the pandemic situation?
Stress	How do you feel when you find yourself in stressful situations? Which strategies do you use to deal with stress? Where do you find support to help you deal with it? How did the stress induced by the pandemic differ from other, traditional, stressful experiences? Which strategies did you use to deal with this unprecedented situation?
Personal development	Which "silver linings" could you obtain from the pandemic experience? In which aspects do you feel you grew as a person during this time?
Happiness	If you had to rate how happy you feel right now, what would be your judgment? What relationship do you have with your family? With friends and/or partners? With whom do you feel like you can share feelings and problems? How do you deal with solitude? How would you describe your social life now?

2.3 Realization of the Interviews, Data Acquisition and Treatment

For this study, 4 interviewers were trained through a 5-webinar course, during which they were trained on conducting interviews and data treatment and discussed together a pilot interview; all but one of the interviewers had previous experience with one-on-one interview protocols. All interviews were realized at distance using the Skype Web 4 software from January 10 to February 25, in Italian language. The recorded interviews where then stored in a shared Google Drive folder and coded for the interviewers and the interviewee initials. *Verbatim* transcriptions of the interviews have then been realized by the same researcher, using Otranscribe software. The goal was to allow for the insertion of tags (relating to the interviewer, interviewee, pauses, laughs, etc.) as well as to obtain high-fidelity transcriptions, required for quantitative text analysis. Translated interviews, with the embedded metadata, were then automatically transformed from.txt to.xml format with a script conversion tool and built into a corpus using SketchEngine software. The analysis that will be conducted includes quantitative analysis through frequency and dispersion analysis, to identify *key concepts* (what is talked about); quali-quantitative collocations analysis (to understand how key concepts are talked about), and qualitative dialogic syntax [24] to understand the possible differences in the language adopted (construction of meaning, different connotations, etc.) between interviewers and interviewees.

3 Preliminary Findings from Content Analysis

The quali-quantitative analysis protocol described in 3.3, as well as the content analysis, are still undergoing, as the interviews cover many different topics and a scrupulous analysis is required to obtain useful indications from the students' interviews. However, her we present the example of a specific topic – the use of lesson recordings by students - which highlights how this mixed – method protocol can be effective, using quantitative analysis to identify general trends and qualitative studies to obtain more in-depth insights, towards building better instructional experiences for students. The following are the translated excerpts from four different students to the question "Which were the most common didactic modes (synchronous, asynchronous)? Which did you prefer and why?" that focus on the accessibility of recordings of online video-lessons.

[001, M, worker, living in the city, high family income] *Yes, I had a tablet and a pc. The phone… But I prefer the PC. The tablet only to follow the video lessons already recorded. Because I could maybe stay on the bed which was more comfortable. Because sitting all the time is tiring. Because then I also experienced a period of forced quarantine because mom took (…) covid, so I was tired of being on the chair and then I got on the bed to watch video lessons. But if it was live I preferred to sit anyway, however I could write, I could take notes.*

[002, F, worker, living in city, high family income] *I needed to stop, write notes, resume, because they went too fast and I couldn't follow. That is, I either wrote notes or followed. Instead with the recorded lessons it felt much safer to block, write notes, correct, if I did not understand something I resumed. Instead, there were fairly simple lessons where I could easily follow step by step.*

[003, M, non-worker, not living in the city, low family income] (…) *convenience certainly given by the recorded lessons, given that I follow live but then after it is always nice to review the lesson, taking however the most important and perhaps salient moments then unwinding the lessons which instead before was much more complicated in presence, in fact often somebody asked if it was possible to record it and then diffuse it. So "quote unquote" with the lessons already recorded on the computer there are no longer these difficulties.*

[004, F, non-worker, not living in the city, high family income] *For me it is also important that the lessons remain recorded because if I need to review a concept or maybe taking notes I miss a word I can review the lesson in the afternoon and unwind everything correctly. That is, do not miss a single word of the teacher. Something that in university you should be asking: "professor can you repeat? I missed a word." Then a bit shyness, a bit "*mamma mia, *she might get nervous again", often you don't even ask, so you go on writing and there are holes in the notebook because you lack words. So, yes, the fact that the lectures remain recorded is an advantage… It's really a great advantage. In fact, in my opinion it is something that should be maintained despite the fact that it all ended… Even when it all ends. In my opinion it is something that should remain also to facilitate the student. Going in presence yes, absolutely, but if in the morning the lessons can be recorded easily even those who work.*

Despite the interviewer not directly referring to it, the question of video recordings (also called by students *video-lessons*) was a subject commonly brought up by interviewed students. The video recordings that they were referring to are the unedited recordings of synchronous lessons, realized by the teacher and then uploaded on the course platform. What's especially interesting is that not only all the students who mentioned video recordings agreed on their helpfulness, but each of them appreciated them from different reasons, from the possibility to change body position and be more comfortable (001), to pausing the recording in order not to miss important content while taking notes (002), the reduced need to disrupt the "flow" of the synchronous lesson when missing some information and review the content later on (003–004). Given that video recordings are an especially low-maintenance content, as they mostly get only minimal editing (or no editing at all) and were simply uploaded on the platform sometime after the lesson ended, it is clearly something that emerges from student interviews as a low-effort/high gain supporting material for students, not only for those who missed the synchronous lessons. Making lesson recording available and their use by students is certainly not a novel theme (see, for instance, [25, 26]), but has encountered a lot of resistance in Department Councils in many universities, which reflected in distance learning normative. This kind of information is important not only to attest their usefulness for students, but also, in an instructional perspective, to give students further tools for making use of recordings for study purposes (i.e., collaborative note-taking, creation of hyper videos, embedded quizzing, etc.).

As an example of the findings emerged from this in-depth approach toward students' experience is a better understanding of the importance that students attribute to being able to access recordings of online lessons. Students, especially those that were already used to taking notes during lessons in presence, cherished the possibility of watching and re-watching lessons at their own pace as well as the possibility to go over key passages multiple times, developing in the process original strategies to integrate them in their study routine.

4 Discussion and Future Developments

Taken together, the preliminary indications emerging from the different parts of the FOSTER project seem to indicate that, in agreement with the literature, both socio-demographic, contextual, and technological factors played an important role in shaping university students' pandemic experience and developing resilient habits. Obviously, whereas it is impossible or, at least, very difficult to act on socio-demographic and, at a lesser scale, technological factors, it is certainly possible to change some contextual aspects like university digital policies, course organization, and instructional design aspects to promote student perceived health and support their resilience, partly by assessing and motoring their coping styles. This attention to contextual factors could also help address one of the issues that many traditional universities are facing in the return to "traditional", almost exclusively in presence, learning: the fact that students feel less motivated in participating to in-presence lessons [27]; this is especially true for students that do not live close to the city and during the pandemic adapted their lifestyle and their study style to a full-online environment. With these observations in mind, a teacher training program is in development. Its main goal is to promote innovative teaching and learning solutions for blended learning, including the many lessons learned from the pandemic period concerning didactic models, tools, best practices of course management, as well as student-student, teacher-student, and teacher-teacher interaction. Based on the preliminary results of this research at large, the training aims at developing teachers' competences in 1) instructional design (both DL and in presence) 2) teaching and learning strategies (especially group- and team- based methodologies) 3) digital education 4) communication skills 5) assessment practices (formative assessment, self-assessment, project- and product- based assessment). This pilot training will be evaluated and, if the expected results are met, will be followed by a full experimental phase with the comparison between an experimental group and a control group with pre and post-test assessment, and the follow-up assessment in six months. Overall, a better understanding of students' experience in adapting to this "new normality" of higher education can be an extremely valuable resource not only for reflecting on the factors that influenced students' attitudes and beliefs to-wards online and blended teaching and learning, but to provide crucial context to inform instructional design for higher education, to orient university teacher training, as well as to inform methodological choices concerning the organization of courses, the balance between in-presence and online learning, the use of learning management systems, etc., with the final goal of designing better opportunities for teacher-student, student-student and student-content interaction in this new blended environment. Therefore, a better understanding of how university students adapted to the post-pandemic university scenario is instrumental to building the university of the future.

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Methodology and Education

Two years of Blended Synchronous Mode Learning in Higher Education. The Students' Experience Told Through Their Metaphors

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Abstract. Both the documents produced by the main international organizations and the thematic scientific literature highlight the impact of distance learning and blended synchronous learning, introduced with the COVID-19 pandemic. Two years later, what seemed to be an exceptional initiative is turning into an educational opportunity for students and teachers, provided that reflection on these impacts and results helps to inform some changes in the teaching-learning act as a "lesson learned". A qualitative analysis on students' metaphors and representations of their biennial experience in distance learning and blended synchronous learning in two university courses is here presented. In line with the findings of similar studies, possible hints are given to improve the teaching-learning relationship when distance and blended synchronous mode coexist.

Keywords: Distance and blended synchronous learning · Higher Education · Qualitative research · Metaphors

1 Background

In the last two years, we have witnessed a wide and in-depth production of documents produced by both international organizations and the scientific literature on the topics "pandemic - distance learning – teaching-learning relationship".

On one side, the documents produced by the main international organizations, having education and training as their mission, provide some relevant remarks. [1-3]. Some research works attest, on a global and national scale, the fact that, by virtue of the "way of doing school" experienced in the last two years, students expressed anxieties about their ability to partake in class activities, which produced large pockets of learning losses [4–6]. The data produced on an international level, and confirmed in the national

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trend for the Italian case, highlighted: learning losses and lack of motivation; lack of participation; feeling of tiredness, uncertainty, worry; increase of explicit and implicit dispersion; impact on the family and its effect on students' engagement and motivation to learn [7–10]. In any case, in the continuum of the teaching-learning relationship, a problematic image has been given from the students' point of view on the educational impacts of the COVID-19 pandemic [11–14]. On the teachers' side, instead, the following is recorded: similar approach to teaching to the one adopted in the classroom; worsening of teaching quality; difficulties related to new learning environments; organizational difficulties; difficulty of inclusion [14]. This synthetic outline highlights how most of the weaknesses and difficulties occurred in the last two years were, in fact, already present in the educational systems and the pandemic has only intensified them by relegating the introduction of distance learning to a "missed opportunity" [15–17].

Two years after the introduction of distance learning and blended synchronous learning, in fact, what seemed to be an exceptional initiative is turning into an educational opportunity for students and teachers, provided that reflection on these impacts and results helps to inform some changes in the teaching-learning act as a "lesson learned".

Starting from these considerations, supported by scientific evidence-based literature and research, this paper aims to answer the following research question: which teaching-learning act claims can be provided, as lessons learned, in view of the main results of a qualitative analysis on students' metaphors and representations of their biennial experience in distance and blended synchronous mode learning in a university course?

To this end, in order to methodologically clarify the use of metaphor in the field of formative evaluation, as we shall see in the following paragraph, it is appropriate to specify the concept of metaphor that has been used, in the context of the diagnostic and formative function of evaluation, as a tool able to restore the subjects' representations with respect to a theme that is deemed important. [18–20].

Starting from the concept of representation of Berger and Luckmann [21], Sebald underlines how representations guide the formulation of conceptual metaphors on the basis of bodily (cognitive and non-cognitive) experience [22]. Although from a conceptual point of view the motivations underlying the formulation of metaphors are effectively considered as representations, from a methodological point of view there is no evidence that thematizes the close dependence between metaphors and representations/motivations.

The metaphor, in fact, gives back a symbolic image through which subjects affectively represent a certain domain of relationship and can be analyzed as a linguistic and mental process, i. e. as a form of knowledge and reality through which many things are combined and related by emotion. [23]. The metaphor, therefore, "has the power to relate two domains (cognitive and emotional) using the directly appropriate language of one as a lens to see the other" (p. 87) [24]. Even Bateson considered the metaphor to be "the main feature and organizational glue of this world of mental processes" (p. 59) [25] or, as Lakoff and Johnson [18] (p. 24) pointed out, "the human conceptual system is structured and defined in metaphorical terms". Asking learners to express themselves metaphorically is thus a form of communicating the meaning they attribute to the experience. The metaphor, in fact, can be used in a didactic context insofar as it generates knowledge about how subjects interpret and categorize their contextual relationship with a domain of experience [26, 27]. From this point of view, it should be emphasized that life experiences feed metaphors which, in turn, produce cultural representations. The latter, again, recursively feed both metaphors and experiences [28]. In light of this, it is interesting to explore metaphors in terms of formative evaluation [29] to explicate, in a teaching activity, the evolution of students' cultural representations with respect to a topic such as the one chosen for this article and reported in the research question: What indications do the metaphors and the reported motivations offer regarding the way in which students have lived distance learning in a university course during these two years?

In this regard, the use of the metaphor in the context of formative evaluation allows us to specify the role that this function of assessment takes in fostering the students' critical elaboration of the different ways of learning, as well as in exploring and correlating the ways in which subjects operate in a given domain of experience with respect to their possible areas of development. Formative evaluation has been used as a self-evaluation strategy by students in order to improve their awareness processes on the teaching experience carried out in the two academic years [30]. Its results can provide a basis of useful information for an evaluation of the university strategies. The formative evaluation that accompanies the re-reading of the students' experience in these two academic years, characterized by distance learning, guides its reading and re-interpretation [29], also acting as a self-regulating instrument of the learning process. From this perspective, the students' explication of the representations and latent processes of affective symbolization of their relationship with the context represents a key to the pedagogical management of training situations as an opportunity to learn how to mobilize resources acting competently according to the context. Lastly, the use of metaphors in the formative evaluation, with respect to the results that will be presented below, emphasizes the need to rethink the teaching-learning relationship and to improve the teacher's and student's reflection on both classroom daily practices and their representations about them [31].

2 Materials and Methods

Consistently with the research question, it was deemed necessary to investigate how some university students experienced distance learning in two courses of the academic years 2020–2021 and 2021–2022. This in-depth study was carried out by means of qualitative research with an exploratory purpose, aimed at analyzing the metaphors and underlying motivations formulated by the students in relation to their learning experience. For this purpose, the research involved 26 university students attending two courses of pedagogical disciplines at UNINT, delivered by Salvatore Patera, in 2020–2021 (T0) and 2021–2022 (T1). Both in T0 and in T1 the students were the same and in both cases they all attended the same university courses, in addition to that presented in this paper.

The detection of the metaphors and motivations, informing similar choices, were carried out in T0 and T1, that is, in two different years when distance learning and blended synchronous mode learning had become something more than an emergency condition. In particular, the data collection in T0 took place at the beginning of the 2020–2021 academic year (October 2020) while the T1 survey took place at the end of the 2021–2022 academic year (May 2022).

A finalized (non-probabilistic) sampling of 26 students was used, having attendance as the main general criterion for choosing them, boosted by their engagement and availability to participate in the research. Consistently with this general criterion, two more specific operational criteria have been selected: the ease of access by the researcher and the expertise of the subjects on the topic analyzed [32].

The overall methodology used to explore the students' motivations is qualitative, with an exploratory research and inductive analysis strategy [33]. According to the research question, the tool used was the self-report with a guiding question: Which metaphor would you use to represent your learning experience of this year's university (pedagogical) courses? What motivation is behind the choice of your metaphor?

Self-report instruments were provided to the target groups as follows: asynchronous administration; written answers on google-form support; set length of the text (200 words). The units of analysis are the metaphors expressed by the students in T0 and T1 and the textual corpus of the motivations underlying those metaphors. In order to develop an inter-rater agreement for data reliability, all metaphors have been analyzed by two blind coders (coder 1 and coder 2), consistently with the overall methodology.

With regard to the analysis of the metaphors, the 'weak' perspective of Wenger and Nückes [34] was chosen for both coders over the usual Lakoff and Johnson's [18] analysis model. Therefore, an inductive analysis strategy and interpretive procedure was used in order to construct conceptual categories of group metaphors and explain them with respect to their semantic affinity.

In order to construct an inter-rater reliability, coder 1 and coder 2 coded the metaphors following the same strategy and procedure just reported. After coding and grouping the metaphors into semantically-related Analytical Categories, the two coders were required to score the different groupings of metaphors. The correlation between the two ratings was calculated for inter-coder reliability using Cohen's K coefficient.

On the other hand, with reference to the analysis of the motivations accompanying the metaphors formulated by the students, the Thematic Coding [35] using MAX-QDA Analytics Pro 2018 [36] was adopted. The analysis procedure was characterized by the following steps [37]: iterative and in-depth reading of the textual corpora reporting the students' motivations to the choice of metaphors in T0 and in T1; coding of extracts of the interviews in sub-codes, by clustering sub-codes into higher thematic codes (HTCs); clustering of HTCs into Qualitative Themes (QTs) with consistent and homogeneous meanings; setting up interpretative ACs for the QTs. The thematic coding strategy in T0 and in T1 is the same, although the data allowed the construction of different categories in consideration of semantically similar but non-superimposable metaphors.

3 Results

The main results highlight how the students' metaphors and motivations have qualitatively changed with respect to the way they experienced distance learning during the considered two academic years. As a first output, we briefly report the results of the analysis of metaphors in T0 and T1.

3.1 Metaphors and Conceptual Categories

As anticipated in the previous paragraph, the metaphors were analyzed by both coders with the same procedure. In this regard, the correlation between the two ratings assigned to the categorization of metaphors by the two coders was calculated in both T0 and T1. This made it possible to determine the level of inter-coder reliability by resorting to Cohen's K coefficient. For the metaphors analyzed, we specify that in T0 inter-rater

Table 1. Metaphors and conceptual categories in T0 and T1

Academic year	Metaphors (n = 26)	Conceptual categories from metaphors (in accordance between coder 1 and coder 2)
2020–2021	1: A leap into the dark (turn on the light) 2: A compass in the Bermuda Triangle 3: A raft in the ocean: we don't know how to row 4: A knife to cut the water 5: A prescribed narcotic pill 6: The sun after the storm (will it pass?) 7.-8: Lobotomy undergone (2) 9: Zapping with the remote control 10. The unexpected 11: Sailing by sight 12: The sign of the times 13: Punch the timecard 14–16: Post-human technology for Neolithic staff (3) 17–19: Technology without instruction manual (3) 20–22: Casting pearls before swine (Students) (3) 23–24: Waiting for Godot (Students) (2) 25: A gym for life 26: From caterpillar to butterfly	A. Feeling of uncertainty and lack of safety by teachers and students (1, 2, 6, 10, 11) B. A possibility that can become a big limitation (3, 4, 17, 18, 19) C. A possibility induced by contingency to avoid taking responsibility (9, 13, 20, 21, 22, 23, 24) D. Pointing the finger at teachers with little confidence even in themselves (5, 7, 8, 14, 15, 16,) E. An opportunity to be seized (25, 26)
2021–2022	1.-5: A chance for everyone (5) 6–10: A Socratic process for me and the teachers (4) 11. From caterpillar to butterfly (cyber) 12–16: Cracked glass half full (4) 17: A challenge overcome through effort 18–20: Homeostasis / Leopard / The immutable 21–24: A missed chance to seize the day / *carpe diem* 25: From grass to the ecosystem forest 26: New world for fearless new inhabitants	F. Opportunities for collective reflection and growth (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 25, 26) G. Crisis as an opportunity (12, 13, 14, 15, 16, 17) H. A missed opportunity (18, 19, 20, 21, 22, 23, 24)

reliability stood at 92% for coder 1 and 87% for coder 2, respectively, while in T1 inter-rater reliability stood at 94% for coder 1 and 91% for coder 2. Because of this value, we present the results of the overall metaphor analysis by considering the outcomes shared by the two coders in analyzing and coding metaphors into semantically-related conceptual categories (Table 1).

Briefly, due to the inclusion criteria formulated in the previous paragraph, the 26 students responded to the self-report in T0 and T1 by giving their metaphors and motivating them.

The metaphors reported by T0 and T1, expressing affective symbolizations of the students' relationship with the distance-learning experience in the two undergraduate courses in pedagogical fields (2020–2021 and 2021–2022), were grouped into distinct conceptual categories for each survey year: 5 conceptual categories in T0 and 3 conceptual categories in T1. In addition, some metaphors were formulated by more than one student and, therefore, the number of occurrences is reported next to the metaphors when that number is greater than 1. For example, for the academic year 2020–2021 (T0), metaphors No. 17, 18, and 19 are grouped as "Technology without instruction manual (3)".

As a trend, we can see that the metaphors varied significantly from T0 to T1. In detail, starting from T0, seven metaphors give the conceptual category (C) "A possibility induced by contingency to avoid the assumption of responsibility (9, 13, 20, 21, 22, 23, 24)" to emphasize the point of view of the students who perceive the risk of a responsibility discharge they are exposed to when using distance learning and not feeling motivated to participate in the lesson. When we keep on exploring the conceptual categories, starting with those with the highest number of metaphors, we find the conceptual category (D) represented by 6 metaphors: "Pointing the finger at teachers with little confidence even in themselves (5, 7, 8, 14, 15, 16)." In semantic continuity with C, category D emphasizes the attribution of responsibility of distance learning outcomes to teachers alone, the latter being considered inexperienced in the use of this new mode. The third and fourth conceptual categories, both composed of 5 metaphors, highlight (A) "Feeling of uncertainty and lack of safety by teachers and students (1, 2, 6, 10, 11)" and (B) "A possibility that can become a big limitation (3, 4, 17, 18, 19)", respectively. These two categories emphasize the feeling of uncertainty and lack of safety toward the new distance-learning experience in T0 because of a great limitation with which students perceive this teaching mode. Finally, only conceptual category E, based on two metaphors, highlights "An opportunity to be seized (25, 26)." The latter deviates semantically from the first four, resulting in a more possibilistic perspective on the opportunity that could characterize the introduction of distance learning.

One academic year later (2021–2022), the survey in T1 returns a different image from the one shown by the first survey in T0. The conceptual categories are reduced to 3, highlighting a greater compactness in the answers provided by the class group. The first conceptual category by number of metaphors is D, with 13 metaphors: "Opportunities for collective reflection and growth (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 25, 26)." This conceptual category reveals a different student viewpoint, more than a year later, which makes it clear that distance learning was an opportunity for both teachers and students to reflect on the teaching-learning relationship in terms of awareness, lessons learned, and different teaching approach. Only the third category (F) "A missed opportunity (18, 19, 20, 21, 22, 23, 24)", with 7 metaphors, highlights how distance learning was perceived, by more than a quarter of the students, indeed as a missed opportunity because it was not fully valued by students or by faculty members.

3.2 Motivations Underlying the Metaphors

Regarding the second output, namely the analysis of the motivations underlying the metaphors developed in T0 and T1, the summary results through MAX-QDA Analytics Pro 2018 are reported. In reference to this output, the link between metaphors and representations is emphasized, the latter expressed in the form of motivations underlying the metaphors chosen by the students.

The background theoretical assumption refers to the fact that metaphors are a means of expressing mental representations. Because of this, a comparison between representations and metaphors is necessary [18, 22, 28, 34]. For the purposes of our analysis here, and for reasons of length and readability of the tables, we do not report the subcodes or the Higher Thematic Codes through which the excerpts from the text corpus of motivations expressed by the students were labeled and grouped.

These Higher Thematic Codes were merged by semantic affinity into Qualitative Themes, taking into consideration a qualitative criterion of content saturation, so that they would represent the motivations expressed by the students in homogeneous groups, as well as a quantitative criterion, designed to represent as many motivations as possible [35, 36]. In this sense, the higher Qualitative Themes "saturate" the Higher Thematic Codes that define them and, consequently, also the Analytical Categories subsequently formulated by number and poignancy of meaning, as shown in Table 2.

Consistently with the results in Table 1, the motivations expressed by the students appear to be connected with the metaphors presented above, in the first column of Table 2, in the case of the conceptual categories already commented on. In particular, two main Qualitative Themes are highlighted for each survey in T0 and T1. These Qualitative Themes were interpreted in the Analytical Categories constructed in the fourth column and supported by the extracts from the motivations in the third column.

In detail, in T0 the Qualitative Theme shows "High uncertainty and lack of trust in oneself and others (teachers and students) with respect to what can be learned through distance learning." In this sense, the AC formulated to interpret this QT is based on the consideration that "The answers highlight, in 80% of cases, the widespread feeling of uncertainty and lack of safety toward distance learning. This uncertainty is directed toward the supposed teachers' didactic incapacity and the conscious lack of responsibility of students towards new forms of learning that require a different mindset." Some significant excerpts in this regard report the students' worried and challenged mood during the first experience of T0 distance learning: "I bet they [the teachers] will use only the textbook and the queries as they did face-to-face (STUD_11). (D)". This is also consistent with what another student expressed: "I am demotivated because of what I feel I cannot do and because I feel that my teacher will not support me (STUD_6) (A)".

Table 2. Analysis of the motivations underlying the metaphors in T0 and T1

Conceptual categories from metaphors (in accordance between coder 1 and coder 2)	Significant excerpts from motivations	Qualitative themes (QTs) from motivations	Analytical Categories (ACs) from motivations
A. Feeling of uncertainty and lack of safety by teachers and students (1, 2, 6, 10, 11) B. A possibility that can become a big limitation (3, 4, 17, 18, 19) C. A possibility induced by contingency to avoid taking responsibility (9, 13, 20, 21, 22, 23, 24) D. Pointing the finger at teachers with little confidence even in themselves (5, 7, 8, 14, 15, 16,) E. An opportunity to be seized (25, 26)	• Everything will be worse, they [the teachers] will induce me to do less than I already do (STUD_4). (C) • I bet they [the teachers] will use only the textbook and the queries as they did face-to-face (STUD_11). (D) • I am demotivated, both because of what I feel I cannot do and because I feel that my teacher will not support me (STUD_6). (A) • If we all (teachers and students) seize this opportunity, it will all be OK; otherwise, it will be worse than it has been up to now (STUD_12). (B) • Finally, we will all prioritize digital skills to learn better (STUD_14) (E)	High uncertainty and lack of trust in oneself and others (teachers and students) with respect to what can be learned through distance learning	The answers highlight, in 80% of cases, the widespread feeling of uncertainty and lack of safety towards distance learning. This uncertainty is both directed towards the presumed didactic incapacity of teachers and the conscious lack of responsibility of students towards new forms of learning that require a different mindset

(*continued*)

Table 2. (*continued*)

Conceptual categories from metaphors (in accordance between coder 1 and coder 2)	Significant excerpts from motivations	Qualitative themes (QTs) from motivations	Analytical Categories (ACs) from motivations
F. Opportunities for collective reflection and growth (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 25, 26) G. Crisis as an opportunity (12, 13, 14, 15, 16, 17) H. A missed opportunity (18, 19, 20, 21, 22, 23, 24)	• We are all committed to questioning how we learned and how they taught us and, in the end, we will get better (STUD_15). (F) • We were discouraged but, in the end, we found a way to continue learning (STUD_2). (G) • Those who wanted to remain in the old conception of teaching and learning have wasted an opportunity to stay in today's time (STUD_3). (H)	Construction of a new way of living the school and not just of assigning the need for change to the other (be it teacher or student)	About 75% of the answers refer to a critical occasion turned into an opportunity to learn to teach (and learn) in a different way, although some resistance (of students and teachers) has remained the same, if not worsened

If this Analytical Category produced in the T0 survey gives a timely interpretation, as seen for the corresponding metaphors analyzed in Table 1, in the case of the T1 survey, there is evidence of a shift in representations of the students' experience in the second academic year (2021–2022). In fact, In T1 the QT describes a change in perspective summarized as follows: "Construction of a new way of living the school and not just of assigning the need for change to the other (be it teacher or student)." Consistently with this Qualitative Theme, the corresponding Analytical Category points out the fact that "About 75% of the answers refers to a critical occasion turned into an opportunity to learn to teach in a different way, although some resistance (of students and teachers) have remained the same, if not worsened".

This AC points out, on the one hand, the propensity that has matured in students to seize opportunities to learn from the distance and, on the other hand, some resistance, albeit reduced, to the way this experience has been translated into practice in other academic experiences. Overall, the main results highlight how the students' metaphors and motivations have qualitatively changed with respect to the way they experienced distance learning.

4 Discussion

In line with similar studies, the present work gives possible hints to improve the teaching-learning relationship, making the most of the challenging opportunity given by the coexistence of in-class learning with distance learning [15–17]. The main results, consistent with the previously-exposed theoretical and institutional framework, focuses on the fact that the pandemic has exacerbated aspects and criticalities already present in the pre-pandemic educational system.

According to our results, the initial sense of uncertainty and the risk of students' motivation and participation loss are confirmed, just like the students' loss of confidence in the ability of teachers to operate within the framework of media education (T0). Whatever the initial criticalities, they have frequently been translated into learning opportunities for students through distance learning (T1). It is important to highlight that the changes that occurred between T0 and T1 undoubtedly depend on the students' relationship with the academic context. A subsequent quantitative study will explore the role of other contextual variables (teaching strategies adopted in other attended courses, etc.) in order to understand the role played by contextual factors with respect to the changes highlighted from T0 to T1.

The educational challenges, consistent with rethinking the representations and practices of the teaching-learning relationship, consider both the cultural models of teaching and the cultural models of students' approach to learning. In this sense, teachers can enhance technical aspects related to the use of technology in teaching but, above all, they can deeply rethink the cultural aspects inherent to their teaching in the way of conceiving and implementing it, based on their understanding of how students learn today and the meaning they both give to teaching, studying and learning [16].

The main educational indications of this work involve the importance to enhance teachers' digital competence (DigCompEdu) and the development of transversal skills (LifeComp) in students, in order for them all to be able to better cope with the uncertainties of a changing world [14, 38].

At the same time, the use of formative evaluation (i.e. through self-report), aimed at exploring students' representations of both how they learn and the meanings attributed to the teaching-learning relationship [29], can be useful to develop students' 'learning to learn' competence, including both the "thinking skills" and the "prospect of hope", thus cultivating their willingness to learn that might in time improve their desire for motivation [10].

5 Conclusion

Albeit involving a small number of students, the results provided by the use of metaphors have shown how students affectively represent a domain of experience, proving how the metaphor, used in the context of formative evaluation, represents a valid tool when used to promote processes of reflection and awareness in students about the way they learn and the meaning they attribute to their experiences [12, 13, 26, 29, 30]. Nevertheless, the results that emerged are consistent with what can be found in the international and national scientific debate [12, 13].

This research shows how it is possible to arrive at considerations aligned with the literature on the impact of distance learning using an innovative, formative assessment method such as the one proposed. However, although a consistency of the results was desirable, from a methodological point of view the use of this formative evaluation strategy to explore the students' point of view complemented by other types of data collection was not yet investigated.

In summary, the modification of the representations (metaphors and motivations) of the students in T1 with greater engagement in distance learning is consistent with the positive results obtained in other research in which innovative teaching is adopted with the use of formative evaluation.

Finally, the main limitation of the work is that it does not allow the generalizations of the results, due to both the small number of students who took part in the activities and the choice to carry out a qualitative work with preliminary results. In addition, given the limitations in the length of the text, the data collected in two reflective settings carried out after the data produced in T0 and in T1, relating to the students' greater awareness and reflexivity, are not reported.

In further research, the competent acting of the students will be correlated according to the metaphors, the motivations and, thus, the representations they have produced as the mindset that guides their competent acting.

The next steps to be taken to improve the methodological approach could be, on the one hand, to share the database and so promote inter-coder agreement processes also through the use of different analysis techniques (i.e. content analysis with CADQAS), in order to compare the results and corroborate the methods of metaphor' analysis.

On the other hand, it could be useful, in such experiences, to evaluate through empirical and statistical verification whether the change in metaphors and motivations of students from T0 to T1 can be reasonably attributable to the teaching in academic courses.

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An Autoethnographic Approach to Faculty Development Through a Longitudinal Analysis of a Co-taught Workshop

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Abstract. The present contribution explores how a co-taught workshop, designed and delivered in the last two academic years within two curricular disciplines of the third year of the degree course in Science of Education at University of Macerata (Italy), took advantage of autoethnography as a reflective method to enrich the interdisciplinary relationship between the two professors involved and their mutual growth in terms of instructional design and teaching practices. The exploration of Self as a data source allowed both researchers (in their teaching role) to reflect on core areas of faculty development in connection with the specific co-teaching style they adopted. Autoethnography allowed all the involved actors (students and professors) to visualize a transformative direction in their academic identity and professional growth. The discussion of the results is based on a content analysis of different data sources where all the data were triangulated in a double connotation, that is, between professors and among the different sources in an iterative process.

Keywords: co-teaching · faculty development · autoethnography

1 Introduction

In the last two academic years a joint workshop was organized within the courses of "Educational Technology" and "Intercultural Pedagogy", run in the first semester of the third year of the degree course in the professional socio-pedagogical educator curriculum (University of Macerata, Italy).

The reference framework was outlined starting from the theories of complexity [1, 2] and the need to activate laboratory dynamics of situated learning [3] in which the students, in the last year of their academic training, could represent themselves and identify with a work team. The challenge of joint professionalization – among students, professors, and the management of the class group – has been reinterpreted in a transformative key [4] on different levels. It is important to underline how the processes of reflexivity concerned all the subjects involved, in a logic of self-reflection and clarification of the meanings of the path undertaken.

The planning of the activities prompted the professors to reflect on the importance of proposing a format in which the meta-competence of "learning to learn" was more

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explicit (for both students' and professors'). This competence is defined as the ability to pursue and persist in learning and to organize one's own learning, including through effective management of time and information, both individually and in groups [5]. Starting from this point, the workshops were planned as experiences in which the responsibility of the student was definitely interconnected with active teaching methodologies, and it was essential to gain greater awareness of the didactic education approaches used [6].

This required a creative imagination of participation, experiencing the workshop directly with an interdisciplinary objective: investigating the intercultural dimensions of the concept of travel (*Intercultural Pedagogy*) through digital autobiographical narrative artefacts available on the web (*General Didactics and Educational Technology*).

Starting from the definition of the topic, the professors opened a dialogue on the significance of the proposal in their respective disciplines, intercepting training trajectories that also supported a fruitful scientific and methodological dialogue at the research level. This step was essential to increase the motivation of the professors with a similar educational background but with different specializations.

The challenge was on different interconnected professional levels; the identities of the professors-researchers and the possibility of co-creating interdisciplinary paths drove them on in their reflexivity, in terms of didactic planning and educational significance. Subsequently, this paradigm was articulated in the conversation with the student community in a professionalizing laboratory mindset. In this regard, a space for reflection has been generated, in which the images, the representation and the identities of professors and students take on further reciprocal interpretations.

2 The Context of the Study

The project-based workshop was co-designed and co-taught by the two professors of "Educational Technology" and "Intercultural Pedagogy" and was meant as a "cluster" within the two different parallel courses, but the whole courses in their rationale was designed and managed taking into account the co-taught cluster. A relevant element concerns the voluntary participation of students who have chosen to attend the training proposal and to subdivide into interest groups.

The chosen hands-on approach for the workshop had the twofold objective to:

- improve the learning process for the students through the engagement in an interdisciplinary group work in order to reflect on both subject matters and their entanglement on a theoretical and practical dimension;
- improve the professional growth of the two professors involved, through their commitment to identifying/designing a proper activity to be developed by students, sharing the management of the teaching practice and performing assessments.

The co-teaching experience was designed with several styles and postures of the professors, in order to facilitate and stimulate the participation of the students both individually and in the groups. The experiences realized in the academic year 2020–2021 and 2021–2022 were organized in different ways, due to the effects of the COVID-19 pandemic. In the first academic year, the activity was online (36 participants working in small groups), and in the second academic year the activity was blended (38 participants working in small groups). In both academic years the professors used asynchronous tools (discussion forum and collaborative writing in LMS OLAT) and synchronous tools (the videoconferencing system TEAMS) with a duration of 14 h (in last three course weeks). The decision to deliver the activities at the end of the semester of lessons and in the final part of the courses facilitated a disciplinary study by students in the respective subjects. This allowed the students to have more knowledge and interpretative tools to start interdisciplinary discussion groups and design the final restitution. Likewise, the dialogue between the professors on the progress of the course programme made it possible to highlight key and critical points that emerged step by step.

The future educators critically experimented in a collective dimension themselves through problematizing logics that are typical of their profession. The university curriculum can design training modules strongly connected with socio-educational contexts, even starting from joint teaching programmes. In this regard, the transversal dialogue solicits students' meta-reflection and the implementation of laboratory dynamics in which the learning process assumes experiential and community connotations [7, 8].

Participatory teaching can encourage the training of professional identities capable of regenerating inclusive and proactive social environments. In small groups, students perceive themselves as members of a working team, experiencing collegial dynamics, through simulations, case studies, open discussions and the implementation of ideas. In the laboratory spaces, new knowledge and collective skills can be promoted [9], strengthening a joint reflexivity that is useful in facing social changes [10, 11] through a huge set of soft skills put into action during the experience [12].

As far as the professors promoting the initiative are concerned, it was very relevant and motivating to observe the students' sense of co-responsibility and their ability to share and achieve educational objectives. The cooperative spaces in which different personal and professional identities have been enhanced have also solicited dialogue between the two professors through exploration and narration of their own self, as well as of shared empowerment [13, 14].

Explaining this path within a training module carried out in co-teaching means enabling students to critically reflect and increase their awareness of the experience conducted, enhancing the sense of discovery and wondering as a way of reading subjective processes and relationships that characterize socio-pedagogical professional profiles [15].

At the same time, the mutual trust between the two professors has supported the processes of shared choice and revisions of the proposals which, over time, in a didactic formulation based on recurrence and attention to the development of meaningful relationships, have implemented new ways of co-planning and definition of feedback tools and methods of documenting what has been learned.

It is very important to underline that the voluntary nature of the students corresponds to the free choice of the professors to initiate a shared experimentation with the class and with themselves, as training professionals, in close contact with the learning environments. The interest that led to collaboration has given generative results in the creation of spaces for reviewing the different teaching–learning paradigms, the choice of teaching methods and in managing the relationship with students and between the two professors.

The climate of the formative environment developed gives back to the student community a possible method of interdisciplinary work and the construction of plural thought. Equally, didactic co-planning gives professors back the sense of didactic educational action where different and similar professional identities meet in the learning experience; objectives, challenges and trajectories already known are made explicit, with a strong openness to the discovery of new ways of working together.

The learning process of the experience was scheduled in the following main tasks:

- Steps 1–2: web exploration and analysis of artefacts – Each group of students, consisting of a maximum of 4 members, chose the salient aspects to be explored in relation to the theme of travel as identity migration. Once the criteria and specific dimensions to work on were established, the group searched online for narratives related to the journey in which to find the essential elements to refer to and start the analysis of the material. Students were encouraged to select autobiographical artefacts (in particular migrant life stories) and discuss their formative, value and communicative connotations.

  The professors, supporting the groups – through direct dialogue, remote feedback on the online platform, clarification emails, video calls – used communication skills, formative evaluation and return of intermediate feedback (feedforward), so that the groups orient themselves to take autonomous and reflective decisions [16]. This educational approach favoured a meta-reflection on a style of teaching, which, animating contexts, does not impose itself in a directive way, enhancing the contribution of all and favouring the co-construction of dynamic knowledge. The professors focused on the importance of the research question and on the assignment of work for the groups, to formulate them clearly, without making it mono-directional, through stimuli questions that facilitated a more aware reflection of the students.
- Steps 3–4: a selection of artefacts and an instructional design of a lesson plan to be presented collectively to the whole class. Once the materials to be used had been chosen, the students designed a training action aimed at enhancing the autobiographical narrative in the social sphere, defining the target to address and the methods of sharing. The planned proposal was discussed with the whole class, through a face-to-face and / or online presentation in which all students were the protagonists of peer learning (in groups and with the reference class) [17, 18]. The professors first supported the design choices and the negotiation of shared knowledge in the small group, and in the final phase they gave a formative evaluation of the class discussion, identifying the strengths and criticalities of what had been achieved.

This process opened up space for dialogue between students and professors, encouraging an additional level of professional reflexivity, as part of a commitment to didactic planning in close interdisciplinary connection. The cooperative dynamics had a proactive reflection in the didactic choices and in the relational postures of all participants – students and teachers – strengthening the value of co-teaching and co-learning. The solicitation of the professors' professional development is mainly based on the commitment to common reflection and the desire to generate experiences with a formative impact of mutual learning.

The co-teaching experience has assumed considerable professional value for the professors involved, as the pedagogical approaches and didactic methodologies chosen were discussed. The time dedicated to the planning of the activity prompted the start of scientific research and the re-generativity of thought. The recursion and longitudinality of the training proposal that continues to evolve over time, allows the critical observation of the learning processes in the situation and the ways in which university professors can decide to co-design teaching paths in which interpersonal, interdisciplinary and professional intermingling is consciously chosen and researched. These challenging and meaningful movements prompt numerous reflections on faculty development and the impact on the quality of teaching. Some trajectories will be further explored below, highlighting the processes, paths and outcomes of what has been achieved so far.

3 Research Approach

The research is framed under a qualitative approach with autoethnography as a selected strategy of inquiry with the application of different methods of data collection during the longitudinal study and a twofold objective about the effectiveness of the co-taught format: (1) for students' engagement and group work modelling effect; and (2) for the professional growth of both the professors involved. The present study will just focus on the transformative potential of co-teaching for faculty development, since a previous study has already explored the impact of the format on students [15] and will be integrated in the applied triangulation of data.

Co-teaching (also referred to as "team teaching" and/or "collaborative/cooperative teaching") [19] has been recognized as a transformative strategy since the 1960s in the USA and England and involved the reorganization of middle and secondary schools [20-23]. Its range of action has spread from the area of inclusion and special needs education [24–27] to a broader area of innovation in didactics and teacher training [28, 29].

In the academic context co-teaching is defined by Robinson and Schaible [30] as any experience where two teachers collaborate both in the design and implementation of a course, which implies the application of student group work techniques. The advantages of co-teaching practices for students (e.g. relation building; communication skills; modelling, etc.) are intensively reported by the international literature as along with the learning opportunities it provides for faculties. The two are reasonably intertwined (e.g. relationship building) and can be affected by the type of roles played by professors in working together [31, 32] and the interdisciplinary connection between two courses addressed to the same group of students [27].

In order to explore such potentialities the authors, in their role as professors, in the two-year-long co-teaching experience adopted a reflective collaborative approach (procedural and epistemological), a reciprocal autoethnographic process.

Autoethnography has largely been applied as a method of inquiry in the professional development of teachers [33, 34]. It can be defined as a "self-narrative that critiques the situatedness of self with others in social contexts" [34, p.710], and involves processes such as reflexivity, narrative inquiry and self-analysis able to provoke critical, emancipatory and transformative social practices [33] for faculty development.

As a fully recognized approach, autoethnography can trace its origin back to 1975 [35] with its formalization as a “new ethnography”, in which the main focus is the Self and the socially constructed identity through a reflective process:

> While the ethnographic field constitutes that of the Other – that location to which the ethnographer “goes” to undertake the research – the autoethnographic field is that of the Self, in which techniques of data collection and recording are reconfigured to account for this inward investigation of the Self. A key element of this process is the charting of identity and those processes of sense-making that individuals engage in as part of the socio-cultural dynamic, with this potentially occurring across entire life-spans, multiple locations and diverse social contexts. [33, p. 371].

Austin and Hickey [33] see autoethnography as “a very powerful ‘method’ of provoking the type of *conscientisation* necessary for authentic community engagement and commitment espoused by critical pedagogues”, which reveals that it is of paramount importance to allow “the social transformative potential of teachers to actuality” [p.371].

If we see faculty development as a collaborative commitment in the academic community, co/autoethnography is one of the approaches to work towards a “scholarship of engagement” [36–38] where a mutual professional growth is reached through collaborative design and teaching practices.

Autoethnography is a widely used approach in qualitative educational research that focuses on the process of teacher professional identity formation and development [39–41] and is not limited to self-narrative in terms of data gathering and analysis techniques, giving the right value to the self (e.g. to the teacher reflections) and others (e.g. to any other actors within the situatedness of the teacher in relation to them). When dealing with co-teaching practices, autoethnography takes an enhanced social dimension, a dialectical relationship between the self, the colleague and practice [39] for a shared critical engagement (co-autoethnography).

4 Data Collection

Data were collected during and after the two co-taught workshop experiences, which covered two academic years (2020–2021; 2021–2022) and are fully described in Table 1. The diversified types of data satisfy the twofold objective of the research, since they aim at gathering both qualitative inputs about students’ artefacts and interactions (trace data) and the professors’ reflections as a source of “self” data (field notes, academic writing, methodological notes).

Table 1. Overview of data types and collection

Timing	Type	Description
Data collected during the first and second co-teaching workshop (November–December 2020 and November–December 2021)	Students' artefacts	Teaching plan Grid of analysis presentation
	Field notes	Professors' observations during the workshop and the final student presentations;
	Trace data	Students' requests via email and online written interactions in collaborative environments as part of the workshop activity; Students' comments and peer assessment during the final presentation (audio- and/or video-recorded)
Data collected after the first co-teaching workshop (March–April 2021)	Academic writing	Published academic paper about the co-teaching experience in terms of methods applied and their impact on students
Data collected after the second co-teaching workshop (April–May 2022)	Academic writing	In-progress academic writing about the co-teaching experience in terms of faculty development
	Semi-structured interviews	Video-recorded interviews with a sample of students
	Methodological notes	Written notes and comments stimulated by the interviews

Some of the collected data have already been used to analyse the students' engagement and group work co-teaching modelling effect and were the object of a published scholarly product [15], while data that pertain to the reflection process of both professors are the focus of the present analysis aimed at highlighting the opportunities for professional growth and the areas of faculty development that can be affected by co-teaching practices.

A more detailed specification needs to be offered about the semi-structured interviews with the students, which were organized online thorough a videoconferencing institutional system. The data were collected thanks to the participation of a sample of (8) students, on a voluntary basis, after the completion of the first session of exams. The professors, who moderated the interview sessions needed to engage the respondents in an atmosphere free from the potential conditioning and tense effect caused by their exam performance. The interviewers used a protocol with a blend of probing open-ended questions, which were accompanied by "follow-up why or how questions" [42, p. 366].

5 Data Analysis and Interpretation

Self as a data source is represented by reflection outputs, which are mainly written notes and comments that were produced during the observation/participation process in different situations: (1) the collaborative organization and activation of the workshop; (2) the students' group work; (3) the presentation of the final outputs by the students; (4) the interviews made with a sample of students.

Those data went under a triangulation process [43], which involved both the professors in the two-year experimentation.

The variety of observational inputs, which led to the core open questions, was affected by the different roles played by the two professors – that is, the "interactive, participant–observer, and rotational" styles [44, p.30] during the course design and implementation (Table 2).

The "rotational" co-teaching style implies a turn-taking modality of teaching where units of instructions, connected to the workshop, were addressed by both professors individually in order to set disciplinary core aspects to be further addressed in co-taught classes. The "participant–observer" style offered an enhanced opportunity to collect data, since the two professors alternated in the roles of either instructor or observer and could, thus, perform a deeper observational process. A further style, the "interactive" modality, was used to offer students a blended support (in presence/online; synchronous/asynchronous) through multiple (both professors) written-based comments/suggestions using different channels (comments on shared online documents of draft student work; e-mail) and real-time discussions during the final presentations of the outputs of each group work.

Table 2. Co-teaching and reflection inputs

Co-teaching style	Professor role	Open questions
Rotational	Both professors individually addressed the chosen topic assuming a disciplinary perspective	What effort is required when designing and performing a co-taught workshop (14 h) within two different courses (each 48 h)?
Participant–observer	Both the professors alternate in co-presence, taking either an instructional role or an observer role	How do we (me and the other professor as observers) interpret a didactical event? What tacit presuppositions are guiding the meaning attribution to events?

(*continued*)

Table 2. (*continued*)

Co-teaching style	Professor role	Open questions
Interactive	Active involvement by both the professors, synchronously and asynchronously, for group work and final student presentation	How do we monitor student work and what supporting strategies are we adopting? What value do we assign to group work, and what criteria for an assessment?

The collected data were discussed between the two professors involved in order to highlight areas of potential faculty development in co-teaching. As a result of a process of negotiation of meanings, after a preliminary content analysis [44], five interpretative categories were identified to systematize the discussion of the transformative potentialities of the two-year experience (Table 3).

The chosen categories embrace different dimensions of professional development at the disciplinary and transversal levels, namely: (1) instructional design; (2) interdisciplinary understanding; (3) metacognitive skills; (4) communication strategies; (5) formative feedback and assessment.

The open questions that were stimulated by the different co-teaching styles were put under a focus of attention during the analysis step and linked to a specific interpretative category to frame the results. The first question highlighted the effort required by both professors in terms of course design, since planning and developing a co-taught workshop (14 h) within two different courses (48 h each) necessarily means that the overall instructional design aspects of the two courses had to be reviewed through the lens of the workshop's objectives to better modulate the whole didactical path. Co-designing an interdisciplinary workshop, in fact, required professors to carefully examine reciprocal instructional objectives and didactical approaches (e.g. timing and class organization), and that process fostered a deeper understanding of the choices made within the two disciplines. Even if professors have, in their daily academic life, formal and informal opportunities to share their ideas, strategies and approaches, the concrete effort put in the co-design task made it possible to make a step forward reified by a specific output (a joint workshop). Each professor had to embrace the other's disciplinary perspective and open up her background in an accessible way to the colleague (core contents – language – research aims) in order to present and organize a workshop that could be successfully integrated in the syllabi and engage students with a meaningful didactical trajectory.

Table 3. Reflection inputs for faculty development.

Open questions	Development areas	Transformative potentialities
What effort is required when designing and performing a co-taught workshop within two different courses?	Instructional design Interdisciplinary understanding	Co-designing an interdisciplinary workshop put the involved professors in the position of carefully examining instructional objectives through the lens of the different disciplines (e.g. core concepts) and of the disciplinary didactical approaches (e.g. timing and class organization)
How do we (me and the other professor as an observer) interpret a didactical event? What tacit presuppositions are guiding the meaning attribution to events?	Shared metacognitive reflection (presuppositions, expectations, reasoning process, etc.)	Being an observer in the co-presented classes put the involved faculties in the situation of sharing own focuses of attention related to the didactical event. The objects of observation may be different (one specific student's behaviour; the group discussion process; the impact of the peer support; etc.) and can help professors differentiate expectations in outcomes
How do we monitor student work and what supporting strategies are we adopting? What value do we assign to group work, and what criteria for an assessment?	Communication strategies Feedback and assessment	Blended group work (present, online) and teachers' collaborative supporting strategies through different channels allow an enriched communication flow between the two professors in order to provide an effective feedback to students

Observing the colleague in action was of paramount importance to visualize each professor's metacognitive reflections by sharing presuppositions, expectations and the reasoning process in the note-taking process (especially in methodological notes). Playing the role of the observer during the co-presented classes classes put both professors in the condition of comparing their own objective of the observation (one specific student's behaviour; the group discussion process; the impact of peer support, etc.). That process represented a highly formative step towards the accomplishment of an analysis of their most deeply held inner beliefs.

The monitoring actions, activated to sustain student group work, represented a collaborative effort for the two professors who maintained an interactive style and analysed each other supporting strategies on three different levels: (1) communication (preferred/most used channel: short written comments; e-mails; oral interventions; (2) kind of feedback (task-level; process-level; self-regulation level; self/motivational level) [45]; (3) final assessment (negotiation and remodulation of criteria). The analysis of the methodological notes, taken during the monitoring process, highlights a focus, in both professors, on the colleague's supporting actions and the explication of reflections on the acquisition of a new professional awareness in terms of a variety of strategies to adopt (e.g. "I noticed that, at the beginning, I was mostly focussed on task-level feedback, but reading my colleague's comments made me reflect on the opportunity to balance my interventions in a different way"). In the discussion of this specific category the exchange that occurred between the professors after the students' interview was also relevant, whereby more than one respondent reported the change in the approach towards tasks due to the different supporting actions that the two professors offered jointly during the process. The triangulation of personal written notes with the data gathered thanks to the interviews made it possible to add a further level of reflection on the effectiveness of the multiple interactive styles adopted in co-teaching to support the students' learning paths, mainly in terms of motivation and commitment, results that integrate the analysis made during the first year of the experimentation [15].

6 Conclusions

Autoethnography applied to a co-teaching experience allowed all the involved actors (students and professors) to visualize a transformative direction in their academic identity and professional growth. Students had the chance to reflect on their attitudes, skills and motivation through their active engagement in the interdisciplinary group work and could also appreciate the collaborative dimension in terms of their professors' effort in designing and activating a joint workshop. The modelling effect was clearly addressed in students' responses to interviews, statements that appear aligned both with the first-year data [15] and the international research on the appraisals of collaborative teaching [31] while reporting a sense of comfortability in receiving support by two different professors with their own specificities and modalities. Moreover, students stressed that they felt more confident in asking for help and talking about their doubts when the two professors were co-present, a specification that makes the professors reflect on the balanced and successful results of the adoption of an interactive style in co-teaching.

A further mention needs to involve the role of the proper balance between the synchronous/asynchronous feedback flow for the development of supporting strategies by professors: the decision to use asynchronous communication tools (collaborative writing spaces) to integrate oral real-time interventions with written comments on students' work in progress was not only an additional scaffolding for students, but also an opportunity to modulate and integrate reciprocal feedback at the task, process and self levels [16] and this was possible thanks to a blended space–time of learning. The "blended" learning format has also been affected by an ongoing transformation due to emerging forms of collaborative teaching [46]; the presented joint workshop revealed its strengths in terms of the digital space as a supporting environment for students during the development of the process and as a reflective archive for professors with a source of rich written-based data (comments, suggestions, etc.).

All data were triangulated in a double connotation – that is, between the two professors and among the different sources in an iterative process that undoubtedly represented an additional potential for faculty development in terms of the adoption of research procedures [39] for researchers/professors that are used to different kinds of methodologies given the different epistemology of the disciplines and areas of application.

Co-teaching revealed a demanding and challenging format, both in terms of instructional design and implementation, but was highly rewarding in terms of the students' motivation, engagement and purpose-fostering approach in their growing identity as future educators. Autoethnography was a necessary quality step to enable the professors involved to apply a continuous reflection process and learn how to consider themselves as a primary data source in their professional growth.

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Teaching Cybersecurity: The Evaluation of Nabbovaldo and Blackmail from Space

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Abstract. Interventions to raise awareness and promote cybersecurity behaviors have recently become widespread, but much still needs to be done to broadcast this knowledge on a large scale. Video games (i.e., serious games), can represent a valuable way of building digital skills because they are shown to improve learning through active involvement, by increasing and motivating emotional connection to content. The Ludoteca del Registro.it developed a video game named "Nabbovaldo and blackmail from space". In this study, 270 students ($M_{age} = 12.66$, $SD = .70$) from four different schools in Tuscany were involved in a project aiming: (a) to evaluate the video game in terms of satisfaction and usability, (b) to understand the effectiveness in improving cybersecurity knowledge. The results show that the video game was appreciated by the students. A great improvement emerges in the student's cybersecurity knowledge, particularly for those who have played the videogame. Video games represent an extremely important educational tool, to be exploited and further integrated within our schools. Future studies have to replicate these results, adding a control group to reach a more structured research design.

Keywords: Videogame · Serious Game · Cybersecurity

1 Introduction

Children and adolescents spend a lot of time on the Internet, an instrument used for many different activities: studying, watching movies and/or TV series, making new friends, and keeping in touch with others [1, 2]. The usage of Internet, with its numerous benefits, opens up space for new possibilities of communication and learning, but it is also important to underline the different risks and dangers that come with it [3]. A survey by EUKids online [4], conducted on 25.101 children between the ages of 9 and 16 and belonging to nineteen European countries, shows that 11% of participants reported data abuse. Although there are differences between the countries, these data tell us that most children are often not aware of online problems. In Italy, communication and interaction skills in young people are well developed; on the contrary, those related to content creation and navigation are still low [5].

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But it is precisely by surfing the Internet in an unsafe way that you can be vulnerable to cyber-attacks. If children spend so much time on the Internet, they must be aware of cybersecurity. Indeed, even on the Internet, there are rules to follow and to respect, to protect both the users and the website integrity. However, the terms of conditions and use of a website are hardly ever read by those who surf within the websites [6]. If this is true for adults, it is even more true for children. As well documented in some studies [7], this is due to several factors: indeed, users struggle to grasp all the implications of the clauses they find and often end up not reading them, but still accepting the terms of use to be able to access the website. This is an example of insufficient attention we often have when browsing online, and it is precisely this lack of focus that makes us potentially vulnerable to cyber-attacks.

Interventions to raise awareness and promote cybersecurity behaviors have recently become widespread, but much still needs to be done to broadcast this knowledge on a large scale [8]. While many prevention programs for online dangerous behaviors (i.e., cyberbullying, online sexual exploitation, etc.) have been developed, few frameworks have focused on issues such as online fraud, hacking, and identity theft. These kinds of problems should not be underestimated [9].

Among the many skills that a child or adolescent must develop, learning to navigate the Internet safely should be included. Although in the first phase of the Internet's usage parents can use some parental control tools, the development of autonomy is one of the key points in the growth of young people [10]. Moreover, is not easy to understand the practical implications of personal information's promulgation. In many cases, people don't realize how much sensitive private content is shared online, and how this can represent a source of vulnerability [11].

Video games (i.e., serious games), can represent a valuable way of building digital skills because they are shown to improve learning through active involvement, by increasing and motivating emotional connection to content. Furthermore, they are easily adaptable to different types of learning [12, 13]. These games are based on experiential learning, which favors "learning by doing" [14]. Thanks to the usage of video games, children can be more involved in learning and testing their skills in a safe environment.

The ability to actively explore reality allows you to convey messages much more effectively than theoretical lectures. Within the game it is also possible to act in a "protected" space: both because one can make mistakes without encountering consequences that have too much impact on the person, and because one can act without being judged, and this favors the most spontaneous choice [15]. The game has always been a privileged modality to convey educational messages, and in this logic, videogames represent nothing more than their "extension" in the virtual world.

1.1 Serious Game on Cybersecurity: State of Art and the Novelty of Nabbovaldo

Some video games aiming to educate on cybersecurity have already been developed. For example, CyberCIEGE [16], sponsored by the US Navy and used by government agencies and universities; BigBro [17] and CyberCraft [18], developed by engineering students. All these video games aiming to train the player on cybersecurity, with multiple choice quizzes and a progress monitoring system. However, they require a fairly good basic knowledge of the topics.

Another example is the video game Cybercity Chronicles [19], set in a hypothetical reality of the year 2088 with special agents fighting powerful hackers, a captivating scenery but no adherent to the real and daily online life experiences of the children.

The video game "Nabbovaldo and blackmail from cyberspace" is therefore included in this field, and have some strengths: scenarios and situations presented recall the online life of today's teenagers. Furthermore, it is designed to be brought into the classroom, and therefore to work at school level, and for this reason a desktop version has also been designed. It therefore represents a unicum in the panorama of educational resources dedicated to these topics.

1.2 Ludoteca del Registro.it

The Ludoteca del Registro.it is a digital education project that was born in 2011 as part of the Registro .it, the Registry of Italian domains. In 2013 Ludoteca received the patronage of the Guarantor for Children and in 2019 became a member of the advisory board of the Safer Internet Center Italy [20]. Since 2011, the staff of Ludoteca has met more than 16,000 students, all over Italy and beyond. The mission of Ludoteca del Registro .it is to spread the culture of the Internet to new generations, from primary school to high school. Over time, the goal has always been to find fun ways for teaching the correct use of the Internet, the main topic of this project: its functioning and resources, its history, and its organization. Without knowing the Internet, students cannot fully appreciate its opportunities. The Ludoteca has developed various tools, including the Internetopolis web app and the comics of Nabbovaldo. Recently, the focus shifted to cybersecurity, which is becoming crucial in all contexts of daily life. The idea of developing a framework for IT security arises from the need to promote the culture of IT security in young people, stimulating the adoption of "IT hygiene" practices based on a preventive approach, and knowledge of risks. It is increasingly important to protect) devices and data, to recognize and intervene on cyberspace's risks. To achieve these skills, it is necessary to have some basic techniques: knowledge about threats and computer systems; main types of attacks; countermeasures. But how can young people be actively involved in this type of learning?

1.3 Design Implementation and Development of "Nabbovaldo and Blackmail from Cyberspace"

Before designing the videogame, a feasibility study was implemented. The type of game chosen for the study was a graphic adventure with multiple-choice dialogues, alternated with puzzle and/or arcade-style mini-games, for a total duration of about 1 h of continuous gameplay. The feasibility study led to the creation of a Game Design Document (GDD) including all the elements required to develop the videogame. Then, the development of the game was entrusted to a specialized company (Grifo Multimedia S.r.l). The illustrator and screenwriter collaborated with the external company to ensure the final product matched with the original project, and to guarantee good usability, excellent and faster-paced gameplay (see Fig. 1 and Fig. 2). The implementation of the video game was carried out in different stages. First mini-games were created, to test their performance, then, the Internetopolis scenario was designed. This was followed by the addition of the scenes in which dialogues and actions take place and the creation of the dialogues themselves; the scenes also include a written text designed to assist deaf people and help users retain fundamental concepts - in line with the educational nature of the video game. The dialogue creation provided for a chance to revise their content and make it suitable for the fast-paced rhythm of a video game.

Both the implementation and the design stage involved the skills of several professionals: communication and educational aspects were supervised by Ludoteca educators, scientific validation of the contents was provided for by CNR-IIT researchers, Giovanni Eccher (scriptwriter) worked on dialogues and storyboard, game design experts took care of the Game Design Document (GDD), Gabriele Peddes (cartoonist) worked on illustrations, and game developers allowed the creation of the final product.

The choice to develop "Nabbovaldo and blackmail from cyberspace", entirely dedicated to cybersecurity, represents a push towards the adoption of innovative teaching methods. In fact, "learning by playing" is becoming an increasingly widespread method also in the school environment, useful to make learning more engaging together with promoting the development of transversal skills such as collaboration, problem-solving and critical thinking. "Nabbovaldo and blackmail from cyberspace" is a serious single-player game, conceived as an adventure divided into chapters. The protagonist is Nabbovaldo, a young inhabitant of Internetopolis, passionate about the online world but naive and not really aware of the possible risks. The character's name comes from the italian-slang word "Nabbo", which refers to a person who can't do something well online, and from "Marcovaldo", the protagonist of a novel written by Italo Calvino [21] (see Fig. 3). The game provides a hybrid structure between the "fixed path" and "open world": the player can move freely within the Map, talk to the characters and solve the Mini-games in the order they prefer. Alongside this structure, the plot of the game develops in four main chapters, plus an epilogue. The player moves within five main sections: 1) Settings: external and internal scenarios of the Internet city; 2) Map: the set of various environments on which Nabbovaldo can be geolocated; 3) Mini-games: arcade and game of intuition on cybersecurity issues; 4) Nabbopedia: a small dictionary in which the definitions of technical terms are collected. In addition, he can converse with other characters (Linda, Ada, Dr. Kappersky, etc.), in linear or multiple choice mode.

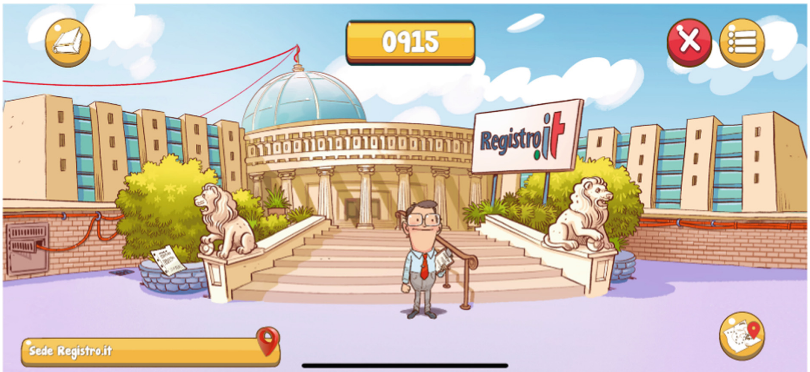

Fig. 1. The Registro.it in the videogame

Fig. 2. A dialogue scene in the videogame

Fig. 3. The protagonist of videogame: Nabbovaldo

2 Methodology

The aim of this work is twofold: first of all, to evaluate the video game in terms of satisfaction and usability by the students of middle schools, and secondly to understand to what extent the video game is effective in improving cyber security knowledge of students.

2.1 Procedure

Participants were students of four middle schools from Tuscany, coming from Livorno, Pisa and Lucca. The schools were contacted through a presentation letter for the project, which explained both the temporal organization of the meetings and the contents and training objectives. The schools have voluntarily chosen to participate.

In January 2021, the teachers of the involved classes attended video game training held by the Staff of the Ludoteca. Subsequently, the classes involved took part in a workshop, conducted by the Staff, where they were explained how the video game works and cybersecurity key concepts were provided. Subsequently, the teachers were able to organize training meetings with their classes, where they could delve into the previously introduced cybersecurity issues. The Staff of the Ludoteca has always remained available for remote support. To assess the impact and effectiveness of the video game, a self-report questionnaire was administered to the students before the first meeting with the Staff and after the conclusion of the project. The survey was anonymous and data were analyzed in an aggregate way. The questionnaire, lasting 30 min, was completed via Google Forms. Since the students were under years 14 of age, the parents filled out an informed consent form to authorize the compilation. This project received the approval of the Ethics Commission of the University of Florence.

2.2 Self-report Questionnaire

The questionnaire inquired socio-demographic aspects (age, gender, nationality, etc.), the use of Social Network and videogames [22] by the students (both in terms of frequency and type), knowledge relating to IT security aspects (both general, cybersecurity specific, and technical-practical), and surfing habits on the Net. In addition, liking-related questions on the video game were included. Questionnaires were created ad hoc. About the cybersecurity knowledge, nineteen items were created, divided into the knowledge of general aspects (eg "I know what online privacy is") and the knowledge of more specific aspects of cybersecurity (eg "I know what a VPN is", "I know what a denial of service attack is"). The scale showed a good reliability index ($\omega = .91$) [23].

2.3 Sample

270 students (mean age = 12.66, SD = .70) of four schools in Tuscany participated in the project. 38% of the sample is female, while 3% prefer not to specify it. The sample is well balanced, with 53% of participants attending the third year of lower secondary school and 47% attending the second. 96% of the respondents are of Italian nationality.

2.4 Data Analysis

Descriptive analyses were carried out using the SPSS software [24]. The results were analyzed by comparing the level of incoming knowledge (ex-ante) with that of outgoing knowledge (ex-post), using ANOVA. Any differences related to gender, age, and effective use of videogame were checked.

3 Results

3.1 Descriptive

Most students spend more than an hour online a day. Excluding online lessons, 43% of participants spend at least 3–4 h a day online, 20% say they spend at least 5–10 h online and 7% are always connected. The Internet is mainly used for chatting with friends, listening to music and/or watching online videos, and looking for news or information. Less often, however, Internet's usage involves activities such as installing a program or using a social network to make new friends. Almost all the students (98.5%) have a smartphone, and the most used messaging service is WhatsApp. Most of them (79%) have a profile on at least one Social Network, and 20% have a public profile. The most used Social Networks are YouTube, Tik-Tok, Instagram and Twitch (a live streaming platform that allows real-time sharing of gaming sessions for the most popular video games).

The students were asked if they had ever had any problems surfing the Net: 9% of them told us that their device was infected with a virus (malware, ransomware, etc.) and 15% were victims of an online scam. Some students (29%) reported some Internet problem but not specify the typology.

3.2 Video Games

As for the use of videogames, 45% of students play videogames more than 1 h for a day, and boys are more likely to play videogames than girls are ($F_{(1, 174)} = 21{,}210$; $p = <.001$; $\eta p^2 = .11$). The preferred types of videogames are Shooter, Sport, Strategy and Sandbox (a video game where the player has a large degree of freedom to explore, interact with, or modify the game environment) or Action - Adventure; and most of students use preferably PS4 or PS5, Xbox or others consoles and smartphones to play.

3.3 "Nabbovaldo and Blackmail from Space": Satisfaction and Usability

Most of the students who participated in the project played the video game (60%). Some students report to have never played: they may have been absent during the workshop meeting with the Staff of the Ludoteca, or they may simply have decided not to play the videogame if the teacher gave it as homework. Anyway, the player group uses the videogame a couple of times a month, only managing to complete the first chapter.

Also, the boys mostly played home alone. In general, the video game was rated by the children as useful, with easy-to-understand game mechanics and operation, and original graphics. The video game was interesting, as well as the issues addressed, and with an engaging story. Through play, students were able to learn new things, including cybersecurity practices and terms they did not know before. In any case, all the students participated in the in-depth meetings conducted in class by the teacher.

3.4 Ex-Ante Results

Regarding the knowledge of cybersecurity, the level of general knowledge is just above sufficient ($M = 6.52$; $SD = 1.63$), while the more specific knowledge is an insufficient level ($M = 4.90$; $SD = 1.96$). The most well-known topics are in fact: "I know what a fake profile is", "I know what online privacy is", while the lesser-known ones are: "I know what hate speech is", "I know what is the IP address" (see Fig. 4, 5). The average level of knowledge differs between males and females only as regards the more specific knowledge: although males also have an insufficient average score ($M = 5.08$; $SD = 2.13$), females seem to know even less ($M = 4.56$; $SD = 1.63$). Furthermore, these levels of knowledge have a very high variability: some students seem to be very prepared, while others seem to know almost nothing. In this phase, there are no differences between the player group and students who have not played the videogame, both for *general knowledge* ($F_{(1, 212)} = 1.257; p = .263$) and for *specific knowledge* ($F_{(1, 212)} = 1.715; p = .192$).

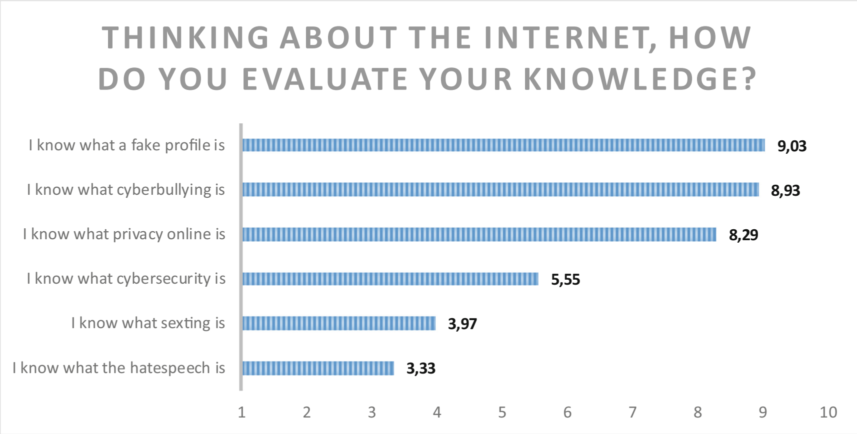

Fig. 4. Ex-Ante Level of General Knowledge

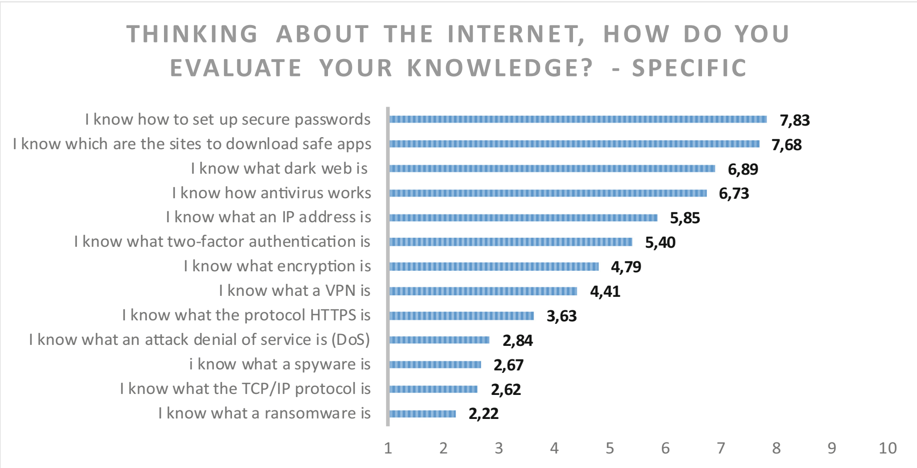

Fig. 5. Ex-Ante Level of Specific Knowledge

3.5 Ex-Post Results

At the end of the project the average level both in terms of general knowledge and specific cybersecurity knowledge increase (Fig. 6, 7 - $F_{(1, 204)} = 109.327; p = < .001;$

ηp^2 = .35; $F_{(1, 204)}$ = 112.625; p = < .001; ηp^2 = .35). Moreover, the improvement is greater in player group. Students who have not played the video game improve their cybersecurity knowledge, but less strongly than students who have played (Fig. 8 – *General Knowledge: $F_{(1, 210)}$ = 97.334; p = < .001; ηp^2 = .32, $F_{(1, 210)}$ = 5.431; p = < .05; ηp^2 = .02; Specific knowledge: $F_{(1, 210)}$ = 103.571; p = < .001; ηp^2 = .33, $F_{(1, 210)}$ = 5.542; p = < .05; ηp^2 = .03*). The knowledge that improves the most concerns many technical aspects of the Net, i.e.: "I know what spyware is", "I know what ransomware is", "I know what a denial of service attack is". Furthermore, the difference between the two groups at the end of the project is statistically significant (*General Knowledge: $F_{(1, 261)}$ = 11.984; p = < .001; ηp^2 = .04; Specific knowledge: $F_{(1, 261)}$ = 15.847; p = < .001; ηp^2 = .06).*

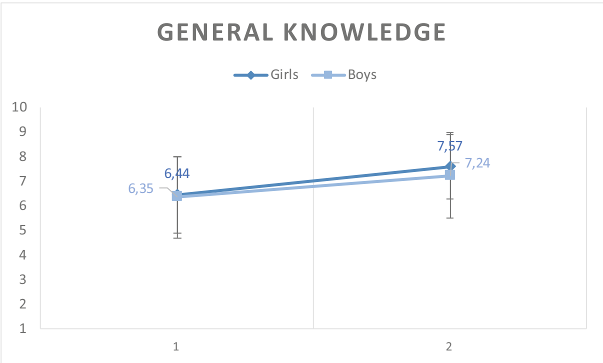

Fig. 6. Pre-post level of general cybersecurity knowledge – Boys and Girls

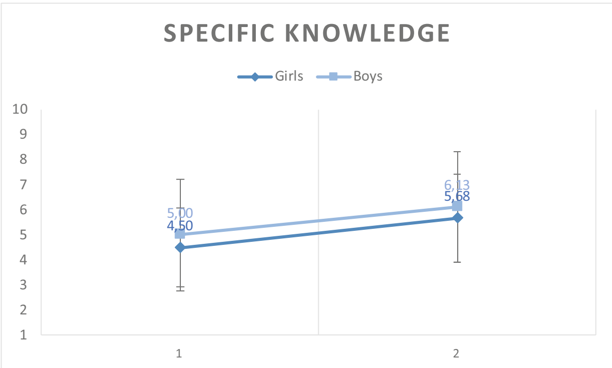

Fig. 7. Pre-post level of specific cybersecurity knowledge – Boys and Girls

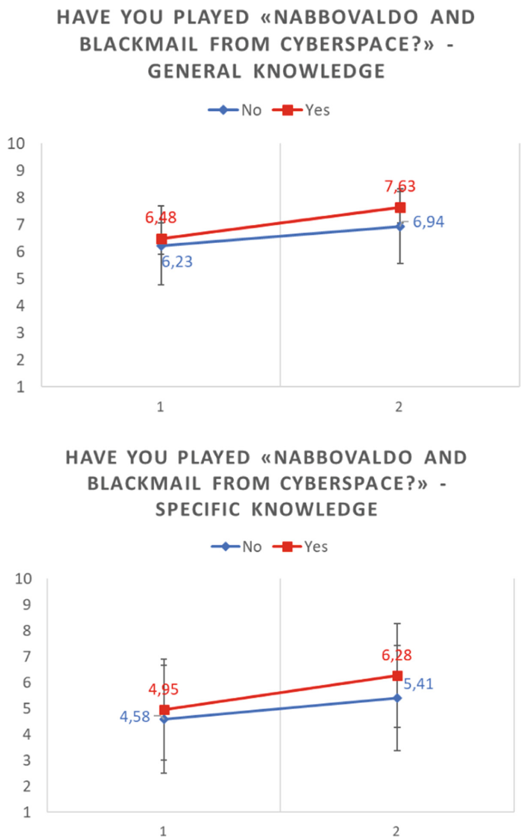

Fig. 8. Pre-post level of general knowledge and specific cybersecurity knowledge – Students who played and Students who not

4 Conclusion

The aim of this study was to evaluate the video game "Nabbovaldo and blackmail from cyberspace", one of the first video games entirely dedicated to cybersecurity to enter Italian schools. Together with the evaluation of the video game, it was possible to collect some data on student's Internet usage and new technologies. A good part of the students stays online at least 3–4 h for a day, almost all of them have a smartphone and therefore have the ability to connect to the Internet wherever and however they want. Young people's perception is being active online 3–4 h a day, but if we think about it, the simple fact of owning a smartphone (which is usually carried around with us) means that we are actually constantly connected.

Indeed, it's not uncommon to run into various kind of problems, such as viruses and cyber-type threats, and students don't always know how to solve the problem. Often, students ask for help from their parents or friends (sometimes even teachers), or simply "shut everything down". This shows that, despite surfing daily, in many cases they have a limited and superficial knowledge of how the web works.

For this, knowledge and awareness of cyber hygiene practices should be one of the main objectives of any online risk prevention program.

As shown in the results of this study, video games represent an extremely important educational tool, to be exploited and further integrated within our schools. Through playing the students could explore cybersecurity situations and scenarios, test their knowledge, and learn new terms while having fun. The possibility to download the game on your mobile device or use the web app version also allows teachers to use it in the classroom and favors group work.

Playing the video game, students show a major improvement in cybersecurity knowledge. Furthermore, those who actually played improved more than those who did not play. This comparison was possible because a question was added into the self-report questionnaire asking the students if they actually played the video game.

4.1 Theoretical and Practical Implications

The results of this study help to popularize gaming as an education and learning tool. The possibility of exploring and learning about situations of potential IT security risk allows you to get to know more deeply concepts and situations that are now part of the daily life of children. Furthermore, even just the theoretical study of certain terminologies allows you to be more prepared in "real" life. It is therefore important to continue working and investing in serious games, to spread this learning method within schools and to train teachers more about the use of these tools.

4.2 Limits and Future Directions

Lastly, this study has limitations: the project was carried out in a very short time frame, and the teachers had a lot of freedom in organizing lessons and classroom activities: which may have affected the results. In addition, some students have told us that video games, while very interesting, may be more suitable for younger children in primary schools. Future studies should therefore bring video games into primary schools, creating more detailed and structured material for teachers and adding a control group to more rigorously test the effectiveness of the video game.

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Self-efficacy and Digital Skill of University Teachers

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Abstract. The intertwining between education and technology has led to a groundbreaking rethinking of the role of university education to prepare students to their future integration in the 21st century knowledge society, rooted in networked teaching, learning, and working environments, and in technological contexts, requiring embedded multimedia digital skills and literacy. Knowledge development is nowadays narrowly related to the enhancement of 21st century skills in agreement with 21st century digital skills. The re-designing of teaching practices for the strengthening of digital skills is becoming a key point of discussion, because less than 50% of teachers often uses technology in class. On the other hand, digital students constantly use technology but the idea that they can be considered highly competent in technology – without training – is nowadays seen as a myth. Both teachers and students may lack digital competence. Digital competence means information and communication technology skills; if applied to teachers, it refers to technical skills but it also implies integrating technological devices and digital resources in educational contexts to reach desired learning goals. In this research it is analyzed the role played by teachers in implementing technology into instruction to enhance students' digital skills. The research is focused on context of University Federico II of Naples. To explore the levels of teachers' technology acceptance in a university context, this research has been carried out with a volunteer sample of 56 university professors from the Department of Humanities of the University Federico II of Naples.

Keywords: Digital Skills · Technology Adoption · Teaching Models

Teaching can be such only in presence.

A University Professor of Humanities

1 Digital Worlds

1.1 Culture Change, Transformation and Transition

Current pedagogical analysis, oriented to the study of educational processes and phenomena, seems to highlight a growing relationship between on one side the needs of supranational systems to guarantee renewed and current citizenship skills and, on the other side, the need of all education systems to translate into practice and actions the indications promoted by community policy makers [1].

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To let interinstitutional mechanism work, a mediation between scientific research, national (and local) school communities, and socio-economic and historical-social variables of society should be promoted. Within this changing paradigm, characterized by a constant transition, general direction choices often find opposing tensions to their realization [2]. Hypotheses development appears to be a continuous intertwining between political guidelines, communities' structure, and situated technological development according to individual and socio-environmental issues [3].

Culture Change is a socio-evolutionary process of transformation and transition which cannot be realized without the support of specific training [4] to foster change, flexibility, and openness related to a local culture of reference [5]. Nowadays, a significant specific training could be oriented toward technology.

The main areas of intervention indicated in the European Framework for the Digital Competence of Educators (DigCompEdu) are to develop reading skills about data and information, adequate levels of communication and collaboration through digital, creation of digital content, safety about the use and sharing of data, ability to solve problems related to digital environments and tools. The DigComp framework comprehends indeed information and data literacy, digital collaboration and communication, digital content creation, ensuring digital safety, and solving technical problems. European Commission focuses on the strategies to be implemented to enhance a significant aware digital presence [6] within digital transition processes.

1.2 Digital Transition Processes

Community strategies of 21st century aim to develop individual experiences within the learning process, and to rethink digital training of those involved in higher education. To live in actual complexity means to improve a balanced coexistence between cultural needs and technical skills to manage the digital world [7].

The cognitive habit to cope with present meets digital competence, which is no more only an intermediary between individuals and environments but also a process in which knowledge itself is re-designed [8]. Learning and communicating thus become aspects which find new spaces and new implementation formulas in the digital world.

Digital world is a new human dimension and a new paradigm which overcome the idea that digital means a media, a support, or an organized infrastructure. Digital transition process is more akin to the birth of the Gutenberg man or Typographic man [9] than to the Fourth Revolution [10], that is the transition from paper book to e-book – content and its form do not change, but tools with which we use it may change.

Even if developing technological tools can modify the same content, however digital transition processes introduce a new grammar of relationships, an innovative use of real and digital environments, of information exchange, of mediated, supported, and virtualized learning, of contents' meaning in different times, spaces, and contexts. Digital is no more a parallel world but a tool for "augmentation" of real data to enhance individual experience: digital can be embodied, situated, and may influence individual corporeality and sociality.

2 Digital University Education

2.1 21st Century Skills and Digital Skills

The intertwining between education and technology has led to a groundbreaking rethinking of the role of university education to prepare students to their future integration in the 21st century knowledge society, rooted in networked teaching, learning, and working environments, and in technological contexts, requiring embedded multimedia digital skills and literacy.

Knowledge development is nowadays narrowly related to the enhancement of 21st century skills – as creativity, problem solving, critical thinking, flexibility, and self-regulation [11], but also interaction, participation, and teamwork [12, 13] – in agreement with 21st century *digital* skills. This is because digital literacy is no more seen only in its technical use as a competence to effectively cope with digital resources and devices, but instead it is today considered as the entanglement of technological, cognitive, and emotional aspects.

The core idea of 21st century skills as investing both learning, literacy, and life fields meets digital skills, even if the first field has a broader spectrum of involved variables. The shared overlapping between the two domains – general and digital skills – has been re-designed through the co-creation of two emerging and interactive research areas – core skills and contextual skills – respectively including technical, information management, communication, collaboration, creativity, critical thinking, and problem solving (core skills), and ethical awareness, cultural awareness, flexibility, self-direction, and lifelong learning (contextual skills) [14].

Since there is a basic common significance ground between general and digital 21st century skills, the aim of university education to integrate students in the current and evolving knowledge society cannot avoid focusing on their continuous overlapping, and the linked consequence is that university digital education has gained a leading role in educational research. The re-designing of teaching practices for the strengthening of digital skills is becoming a key point of discussion [15].

2.2 21st Century Teachers' Digital Skills

Less than 50% of teachers often uses technology in class [16]. Despite technology in education is increasingly required, teachers still need training for digital skills related to a multiplicity of concurrent factors which interplay at different levels within educational systems.

In the last years, The European Commission boosted a developing Digital Education Action Plan [17, 18], which has been recently renewed as a policy initiative for 2021–2027. The original aim was to improve into educational contexts the use of digital technology for teaching and learning by enhancing teachers' digital skills.

Nowadays, the Digital Education Action Plan has been enriched of two priority areas, respectively concerning the development of a high-performing digital education ecosystem, with digitally competent and confident teachers managing user-friendly digital learning content, and the enhancing of advanced digital skills and digital literacy for the digital transformation, which requires specific competences in digital studies.

The teaching approach towards educational technology has been classified in different educational aspects, concerning first the basic skills involved in access to technology and then the competencies related to the use of educational software and gamification in classroom, by computer assisted learning.

Technology-related knowledge, skills, and attitudes of teachers, named KSA, also regard online learning and the design of Open Educational Resources (OERs), Learning Management Systems (LMS), and Massive Open Online Courses (MOOCs) [19]. A Synthesis of Qualitative Evidence (SQD) model has been introduced to explain how technology is embedded in every kind of education, which needs instructional design, and comprehends reflection, collaboration, and the immersion in authentic experiences with related feedbacks [20].

3 Digital University Teachers

3.1 University Teachers' Technology Acceptance

Teachers' motivation and confidence with educational technology is to be really supported [21] through training and professional development because technology in education is considered as a means rather than as an end [22]. Any process of educational change needs a significant rethinking of teachers' practice and behaviors, which – if applied to technology – may widely range from rejection to adoption.

To deepen teachers' behavior toward technology, two theoretical models have been chosen. The Will, Skill, Tool (WST) model defines the position of teachers in relation to technology as their *will*, their own ability to co-create experiences within technological environments as a *skill*, and technology availability and accessibility as a *tool* [23]. Technology Acceptance Model (TAM) can predict teachers' use of technology, and how they will integrate technology and instruction [24].

Technology Acceptance Model [25] concerns teachers' beliefs on use/usefulness of technology to analyze the possible acceptance of a technology system by teachers. This model involves four roots [26]:

- Perceived Usefulness (PU) – the individual perception that using a specific technology will increase personal organization at work;
- Perceived Ease of Use (PEU) – the idea that using a specific technology will be easy and effortless;
- Attitude towards Use (AU) – the positive or negative feelings about using a specific technology;
- Behavioral Intention (BI) – the teachers' intention to implement technology in their own working practice.

The original idea of the Technology Acceptance Model implies that the ease of a technology could solicit its use and could encourage attention and behavioral intention to integrate technology for professional development [27]. A revised version of the model [28] included more aspects potentially influencing technology acceptance, as individual differences, experience [29], social variables, system characteristics, extrinsic motivation, job-fit, effort expectancy, outcome expectations, and contextual facilitating conditions.

3.2 Digital University Teachers and Students

In the 1980s, educational technology was focused on audio-visual formats – audiocassettes, video, slides, … – to delivery lectures. Then, educational technology broadened its scope towards teaching methods to improve teaching and learning relationship. Few years later, in the mid 1980s, there was a large diffusion of personal computing; lower costs and the possibility to communicate by World Wide Web has spread access to digital technology through multimedia, mobile phones, computer-based activities, virtual words, social networking, and so on [30].

Educational technology became a key hub of overlapping aims, as supporting learning processes, empowering study experiences, and overcoming teacher-paced approaches in favor of self-paced study which may be, at university level, characterized by home-based synchronous and asynchronous lectures, digital libraries, and virtual labs.

On the other hand, digital students constantly use technology but the idea that they can be considered highly competent in technology – without training – is nowadays seen as a myth [24]. Both teachers and students may lack digital competence. Digital competence means information and communication technology skills; if applied to teachers, it refers to technical skills, but it also implies integrating technological devices and digital resources in educational contexts to reach desired learning goals.

Teachers tend to apply in classroom what they can easily control, as instruction, knowledge building through discussion, and collaboration. Digital tools and resources need instead a deep re-thinking of teaching strategies to co-create interactive online environments [31], because teachers are more involved in technology introduction if they can self-manage the design of online activities.

In this research it is analyzed the role played by teachers in implementing technology into instruction to enhance students' digital skills. The research is focused on context of University Federico II of Naples. University Federico II of Naples offers a lot of opportunities for teachers who would like to adopt digital didactics, such as the possibility to develop massive open courses, to learn how to build 3D virtual environments, to use mobile learning management systems, and to implement technology into education through online learning.

Nevertheless, teachers' approach toward technology in University Federico II of Naples is still to be improved. Teachers' expertise is needed to sustain students, because technology – particularly, mobile technology [32] and virtual environments [33] – even if educational technology, may negatively affect users' attention and can be related to disorientation and loneliness phenomena, as well as learning through any technological device.

4 Methodology

4.1 Research Questions

In this experimental research, the relation between education and technology has been seen through the eyes of university teachers, which attitude towards or against the use of technology in education can consequently influence students' open or close approach to technology and, more in general, it can regulate their educational approaches.

Research questions concern the organization of a Distance Learning University Course and aimed to understand if university teachers are aware of the role of digital learning communities, collective sharing, critical thinking, and personal differences in shaping the teaching and learning relation. It has been asked to university teachers to define how they imagine content, materials, and graphics in a Distance Learning University Course and if they could allow a more flexible didactic interaction between students and teachers.

4.2 Experimental Plan

Participants. To explore the levels of teachers' technology acceptance in a university context, this research has been carried out with a volunteer sample of 56 university professors from the Department of Humanities of the University Federico II of Naples (25 men and 31 women aged between 34 and 69 years) (see Fig. 1).

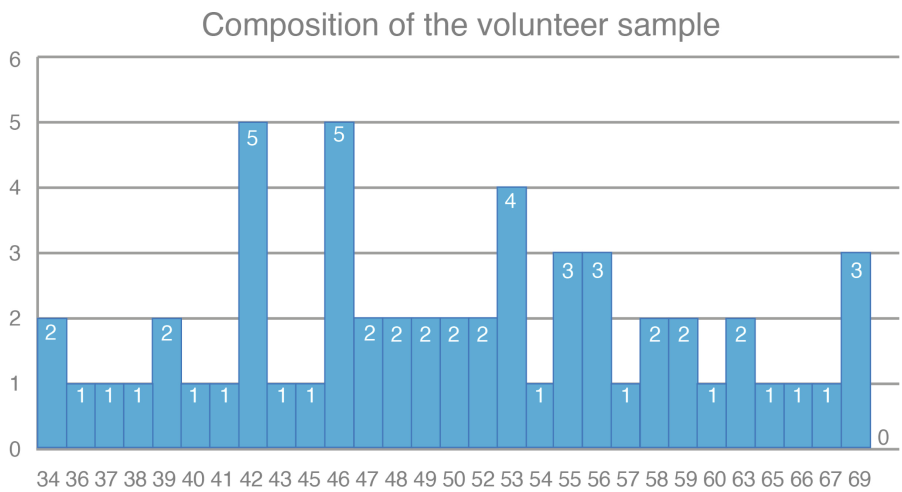

Fig. 1. Composition of the volunteer sample.

Materials. A questionnaire of 6 items has been administered to the volunteer sample. The content of the questionnaire has been identified according to the mobile teaching and learning criteria in educational contexts [34]. It was a closed-ended questionnaire, but it was allowed to teachers to add personal comments concerning the related questions. Questions were about the importance of co-creating digital learning communities; if to encourage formal or informal digital study; if it's appropriate to let students have digital chats on learning materials without the online teachers' presence; how to respect students' personal differences; if students can be allowed to modify their own digital learning environment, co-creating flexible didactic interactions; how digital content should be shaped, provided, and made available. A sentiment analysis of a question about emotions has been added to the questionnaire. Results have been analyzed and discussed.

4.3 Data Analysis

Questions' Results. Results of university professors' attitude towards educational technology has been examined through six questions to understand their levels of acceptance of the use of technology in education.

Question 1. In your opinion, a Distance University Course should include the organization, before starting the lessons, of a digital learning community between students and teachers?

32% of the sample are uncertain, 23% of the sample strongly agree, 22% of the sample agree, while 7% of the sample disagree, and 16% of the sample strongly disagree. The average age of those who strongly agree is 48, while the average age of those who strongly disagree is 56 (see Fig. 2).

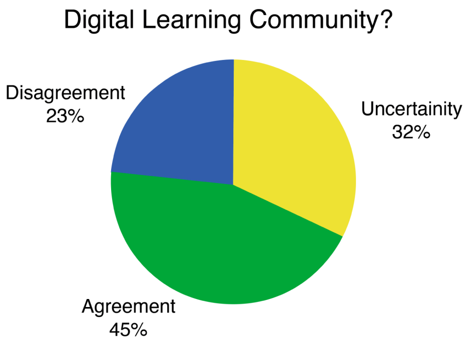

Fig. 2. Question 1.

Question 2. In your opinion, a Distance University Course should carry out:

A. collective, formal, guided study activities relating to the disciplinary topics of the subject being taught, to be followed as online lessons
B. individual, informal study, and research activities, close to the interests of the students, to be understood as autonomous live experiences in the reference contexts of the students

68% of the sample responds to type A and B activities, 29% of the sample responds only to activity A, 3% of the sample responds only to activity B. The average age of those who respond to type A and B activities is 49 years, the average age of those who respond only to activity A is 55 while the average age of those who respond only to activity B is 51 years (see Fig. 3).

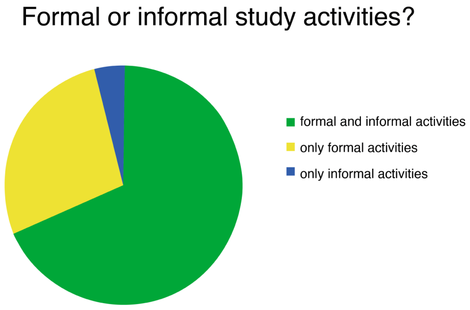

Fig. 3. Question 2.

Question 3. According to you, a Distance University Course should include moments in which students discuss in chat, even without the teacher, the topics they are studying, sharing learning materials, reflecting on of them, beginning to develop and share their own critical point of view?

39% of the sample strongly agree, 25% of the sample agree, 21% of the sample are uncertain, 6% of the sample disagree and 9% of the sample strongly disagree. The average age of those who strongly agree is 50, just as the average age of those who strongly disagree is 50 (see Fig. 4).

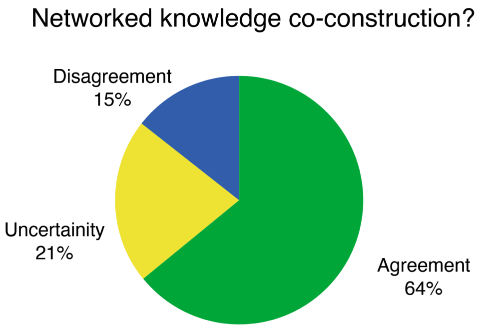

Fig. 4. Question 3.

Question 4. In your opinion, a Distance University Course should consider the personal differences between students:

A. evaluating the previous knowledge and skill levels at the entrance
B. organizing work groups divided by interest
C. other

53.5% of the sample answered A, 39.3% of the sample answered B, 23.2% of the sample answered C. The sum of the percentages does not correspond to 100% because it was preferred to leave the possibility of also answer two options at the same time (for example, answer both A and B) (see Fig. 5).

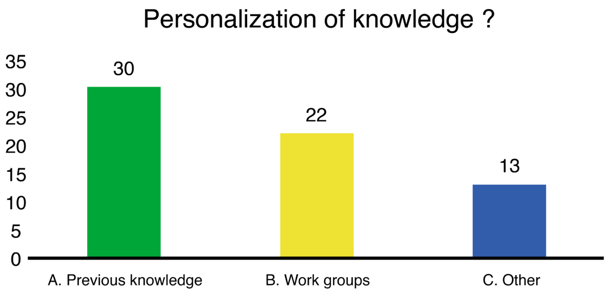

Fig. 5. Question 4.

Question 4 allowed also to give comments, as the following statements:

- No evaluation of previous knowledge: who fails, will change course of study
- Distance Courses shouldn't consider personal differences any more than an in-person course
- Distance Courses should take compensatory and dispensatory measures to support learning
- Personal differences should be first taken into consideration in face-to-face teaching; in Distance Courses different possibilities of accessing online services is added
- Attending courses from home develops a social differentiation from the beginning
- Distance Courses imply differences in the possibility of access
- Distance Courses do not allow to consider personal differences between students

Question 5. In your opinion, a Distance University Course should hypothesize a flexible didactic interaction with the teacher, in which it is possible for the student to propose to modify the distance learning environment? for example students can propose.

A. to integrate the learning contents with further learning materials of interest
B. any changes in the course according to the needs of the groups
C. other

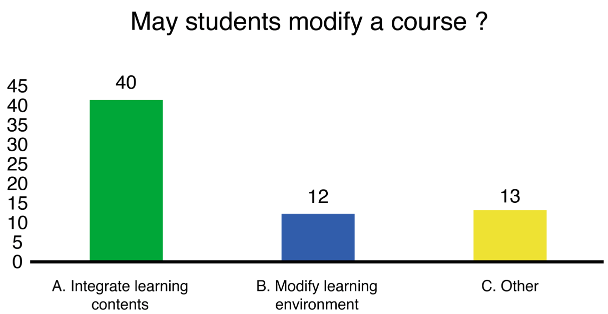

Fig. 6. Question 5.

71.4% of the sample answered A, 21.4% of the sample answered B, 23.2% of the sample answered C. The average age of those who answered A, B or C is 50 years (see Fig. 6).

Question 5 allowed also to give comments, as the following statements:

- In a distance course it is impossible to meet the needs of individuals
- Now it is already possible to add other material of interest to a course content. After all, a university student is an adult individual, autonomous, and free in her/his choices, who can carry on all research s/he desires, with or without my support
- At this point we can directly ask students to write the teaching program and to indicate the bibliography
- Distance Courses do not allow a flexible didactic interaction with the teacher
- I don't understand: the question posed concerns any type of teaching, not just distance learning
- There should be personalized itineraries for individual students
- Distance Courses should not turn into the provision of a service tailored to the 'customer', running the risk of penalizing the quality of the content
- The concrete possibility of requesting face-to-face lessons with suitable structures should be expanded, even with classrooms adequately equipped for audiovisual aids

Question 6. In your opinion, a Distance University Course should have:

A. Easily available teaching materials
B. Resources divided into short contents
C. Educational materials with lots of graphics
D. Digital content provided by students

The sample assigns an approval score to answer A divided as follows: 55% of the sample strongly agree, 20% of the sample agree, 14% of the sample are uncertain, 4% of the sample disagree and 7% of the sample strongly disagree. The average age of those who answer 5 to question A is 53 and the average age of those who answer 1 is 49 (see Fig. 7).

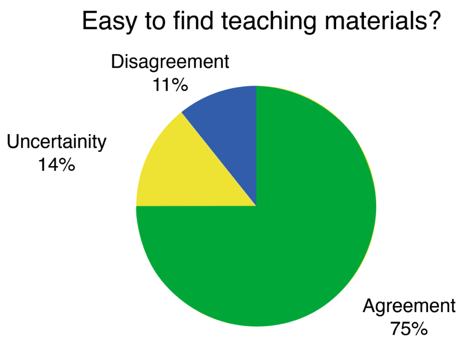

Fig. 7. Question 6A.

The sample assigns an approval score to answer B divided as follows: 12.5% of the sample strongly agree, 12.5% of the sample agree, 21% of the sample are unsure, 23% of the sample disagree and 31% of the sample are very interested disagreement. The average age of those who answer 5 to question B is 52 and the average age of those who answer 1 is 48 (see Fig. 8).

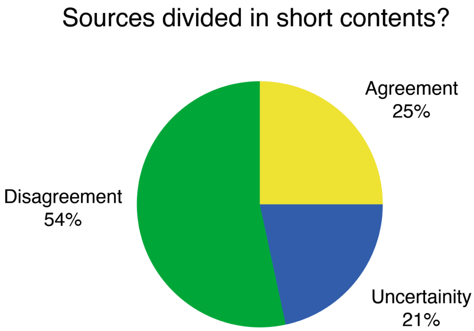

Fig. 8. Question 6B.

The sample attributes a satisfaction score to answer C divided as follows: 8% of the sample strongly agree, 14% of the sample agree, 21% of the sample are uncertain, 18% of the sample disagree and 39% of the sample strongly disagree. The average age of those who answer 5 to question C is 52 and the average age of those who answer 1 is 50 (see Fig. 9).

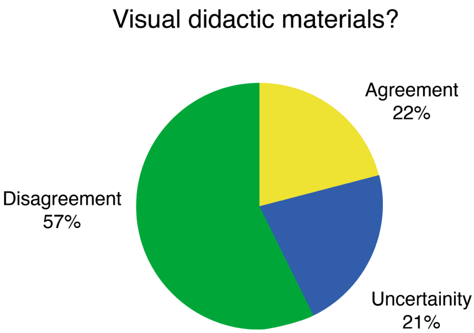

Fig. 9. Question 6C.

The sample assigns an approval score to answer D divided as follows: 7% of the sample strongly agree, 20% of the sample agree, 11% of the sample are uncertain, 23% of the sample disagree and 39% of the sample strongly disagree. The average age of those who answer 5 to question D is 50 and the average age of those who answer 1 is 54 (see Fig. 10).

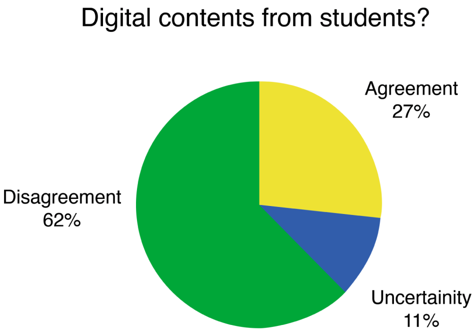

Fig. 10. Question 6D.

Sentiment Analysis Results. To the questionnaire has been added a sentiment analysis of one last question, which is: Can you describe the prevailing emotions that accompanied you during the remote lessons? (see Fig. 11 and Table 1).

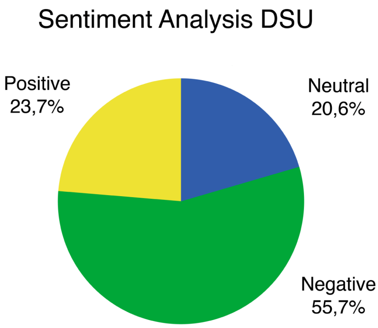

Fig. 11. Sentiment Analysis.

Table 1. Sentiment analysis.

Answers	Classification	Confidence
A potential difficulty in collecting physical feedback	Neutral	0.499
Disorientation due to lack of interaction with students, worry of not always being understood and followed, frustration in not always being able to solicit students' intervention	Negative	0.87
Loneliness	Neutral	0.716
Discomfort and discouragement	Negative	0.953
At first claustrophobia and fatigue. Later satisfaction for the active participation of the students	Positive	0.667

(*continued*)

Table 1. (*continued*)

Answers	Classification	Confidence
Difficulty in understanding the degree of attention and involvement of students	Positive	0.468
Empathy with students in the construction of a teaching module different from the one in the presence.	Neutral	0.487
Dissatisfaction and permanent feeling of superficiality	Negative	0.992
Frustration at the lack of interactivity. Not having adequate skills and knowledge, I was only able to carry out an impoverished version of the more traditional frontal lesson	Negative	0.984
None, in particular, sometimes pleasant because comfortable, most of the time frustrating because face-to-face teaching is much more interesting. Perhaps a question or a survey also on the question of the return of face-to-face teaching should be done.	Neutral	0.506
Tiring, alienating, but also very comfortable. I would not want to give it up	Positive	0.714
No positive emotions	Negative	0.96
A bit of estrangement in not seeing students when speaking; frustration in case of accidental interruptions of the connection	Negative	0.691
Inability to test students' real interest and understanding. Feeling that students were discouraged to intervene with questions and observations	Negative	0.499
Discomfort	Negative	0.876
First, I felt the joy of meeting students despite everything; and then I wanted to exploit my tenacity and the desire to organize my lessons in a convenient way to the new teaching conditions, preparing the materials necessary for the lessons well in advance and sharing them with the students	Positive	0.653
None	Negative	0.615
Concentration and solitude	Neutral	0.657
The same as for face-to-face teaching, but with a greater sense of alienation due to the difficulty of not perceiving the students' reaction to the lesson through all the senses. Partial frustration due to the lower level of interaction, even emotional, with students compared to face-to-face teaching	Negative	0.535
Frustration	Negative	0.97
Tiredness	Neutral	0.556
Worry	Negative	0.95
Lack of a particular emotion	Negative	0.844

(*continued*)

Table 1. (*continued*)

Answers	Classification	Confidence
A bit of effort, and the fear that, as indeed has sometimes happened, the connection would present problems of various kinds	Positive	0.814
Loneliness and boredom	Negative	0.838
Initial surprise, then it became normal	Negative	0.447
Frustration	Negative	0.988
Anxiety	Negative	0.947
Anxiety in relation to any connection problems that could have determined an interruption of teaching activities. Frustration in not being able to see all the students face while some preferred not to use the webcam for various reasons	Negative	0.836
Distortion of teaching	Neutral	0.767
Sadness	Negative	0.532
Fear of not being able to verify the level of interest and attention of students	Negative	0.853
Participation	Neutral	0.923
Discomfort with the impossibility / difficulty of having feedback from students' faces to monitor their degree of interest and understanding	Negative	0.941
More than emotions, I would prefer a rational, shared and open discussion about DAD, especially with a view to overcoming the emergency phase in which it has so far been experienced by many. In fact, more than DAD, I think that what has been experimented so far has been a "technologically assisted teaching", which was limited to "transfer" teaching contents of lessons designed for the physical classroom. I also note that in the last academic year, when teaching was entirely remote, the results were overall more satisfactory. During this academic year, under the so-called blended, the results were instead very depressing: eg. Little interaction of remote students (unfortunately most of them), to the advantage instead of those in attendance, who passed the exam more brilliantly	Positive	0.734
Concern for the effectiveness of the lesson	Positive	0.536
Frustration at the lack of feedback	Negative	0.874
A sense of isolation, an unbridgeable void as you say about the death of a loved one	Positive	0.602
Negative	Negative	0.784

(*continued*)

Table 1. (*continued*)

Answers	Classification	Confidence
Poor perception of the level of understanding by students	Positive	0.664
Finally some digital	Positive	0.889
Strong disappointment and nervousness when in the middle of the lesson the network connection was lost and it was therefore necessary to restore the connection, waiting for the connection to return. In this way the thread of the discussion was interrupted, and the attention threshold of the students was inevitably lowered. Satisfaction with the fact that the lessons could also be attended by those who would have had difficulty in following them in the presence, as a working student or with difficulty in traveling by public transport (with often poor and insufficient connections) or with other personal and family problems. Less stress in general in carrying out the courses, having avoided the stress of traffic and finding a parking space to reach the university before the start of the courses.	Negative	0.833
Initially the emotions were linked to the pandemic context that led to their adoption, then a greater awareness of the real problems of DAD took over: temporary sense of inadequacy, associated with the willingness to take up the challenge; frustration due to the difficulty of direct and continuous interaction (intended as constant two-way audio / video contact, not 'on demand'); fatigue due to a 'static' teaching method, which - beyond the declarations - does not favor but depresses the active participation of students, also mortifying the possibilities of socialization (between students, between teachers and students)	Negative	0.861
Only at the beginning I was anxious in case of malfunction, but then I very much appreciated the modality, as long as it was distance learning and not mixed	Positive	0.767
Frustration	Negative	0.97
Feeling of dissatisfaction	Negative	0.885
The emotions at an early stage were nil: talking in front of a black screen, because hardly anyone turned on the camera, was almost alienating. Over time, however, the cameras were accessed, those photos acquired a face, first, a voice, then, and seeing the students involved and interested was really nice and satisfying	Negative	0.497
Distance and loneliness	Neutral	0.788
Removal	Neutral	0.854

(*continued*)

Table 1. (*continued*)

Answers	Classification	Confidence
Feeling of frustration	Negative	0.865
I have had excellent experiences, which have left me very satisfied with my courses in distance learning. I would have numerous further considerations in this regard	Positive	0.802
A lot of emotional distance and little interaction especially at the beginning	Positive	0.715
Tiredness	Neutral	0.556
Frustration	Negative	0.966
The two years spent in distance learning have developed a relationship that has changed over time. The evolution has been conditioned by computer knowledge that finally well learned have facilitated relationships with students. I think it was a mutual process.	Neutral	0.536
Curiosity and desire to improve teaching	Negative	0.845

5 Discussion

5.1 Cognitive Questions

The first three questions have been intended to understand if the teaching models of university professors were more orientated to direct teaching or to a socio-constructivist approach. Core concepts have been considered the idea of learning community, of situated learning, and of knowledge building. It is interesting to note that in two of the three questions the degree of uncertainty is high (32% and 21%), so revealing that some university teachers have not yet developed a meta-reflective attitude towards their own teaching.

The majority of university teacher believe in the importance of constructing a digital learning community as a prerequisite to a Distance University Course, to sustain students and their relationship with teachers during the learning process (45%); but the 23% disagree. About formal and informal learning, the 68% of the sample believe that collective and individual study, guided and autonomous research, should be carry on together.

This result is encouraging, even if there is still a significant part of the sample (29%) who adopt only formal study to teach disciplinary topics as online lessons, so leaving away one of the basic aspects of online learning, in particular mobile learning, that is to solicit authentic learning through contextual experiences. In the first two questions, the average age of those who agree with a socio-constructivist approach is lower than the average age of those who prefer direct teaching strategies.

Knowledge building – as a process both guided, shared, and self-paced, which promotes critical thinking – is accepted by the 64% of the sample, while still the 15% think it is not to be implemented, showing an anachronistic attitude towards teaching and online learning. There is no evidence of average age differences between the different thinking positions.

In the next questions, teachers are involved in issues more strictly related to online learning, such as personal differences, flexibility in didactic interaction, and methodological structure of a Distance University Course.

The evaluation of personal differences is mainly traditionally considered as a step which anticipate the learning process itself (53.5%), but a significant part of the sample (39.3%) answers that personalization can be implemented in classroom through work groups, so fostering tailored activities for each student.

The question about flexibility in didactic interaction was designed to understand if teachers were open to hetero-direct change guided by students through proposals of motivational learning materials to integrate the course content or anyway through the possibility of challenging the course structure introducing not already foreseen changes.

The 71.4% of the sample was open to the possibility that students could cooperate to the course structure adding some materials, while only the 21.4% of the sample was ready to allow students to change their own course in anyway.

About the methodological structure of a Distance University Course, teachers have been asked how to organize teaching materials, resources, graphics, and digital content. Majority of the sample promoted the easy availability of teaching materials, even if the 11% disagree. The idea of short content in each online unit has been not well accepted by teachers: the 54% of the sample do not appreciate short content, while the average age of who disagree is younger than the average age of those who agree in shortening learning content.

Graphics are considered as well not so useful by teachers; 57% of the sample prefers texts without few or no graphics. As before, the average age of who disagree is younger than the average age of those who agree in shortening learning content. Also as concerns digital content, the percentage of the sample which is contrary to having a collaboration with students is very high (62%).

5.2 Emotional Question

Analysis of sentiment and opinion mining[1] is a field of research based on software mechanisms of an ontological nature, which analyzes opinions, attitudes, evaluations, emotional approaches in relation to certain topics. Answers related to teachers' perception about the use of digital technology for university teaching have been analyzed through the software for social analysis Orange Data Mining.

About the 55.7% of the interviewees expressed negative feelings, with answers ranging from *discomfort and despair* to others who report *dissatisfaction, a permanent feeling of superficiality*, and *frustration at the lack of interactivity. Not having adequate skills, I could only carry out an impoverished traditional version of the more frontal lesson.*

[1] It is assimilated to the broader scientific context of data mining, web mining and text mining, which are processes of reading social phenomena through the analysis of the meanings deduced from large amounts of data, of interventions in social networks or in the opinions of users and customers. The possibility to understand data in their complexity has allowed all social, computer sciences, and humanities to look at phenomena through the analysis of language in its semantic complexity.

The 20.6% of the sample showed neutral views ranging from *no (feeling) in particular, sometimes pleasant because it's comfortable, most of the time frustrating because face-to-face teaching is so much more interesting* to *a greater sense of alienation due to the difficulty of not perceiving the students' reaction to the lesson through all senses. Partial frustration due to the lower level of interaction, including emotional of the students, compared to teaching in the presence.*

Positive judgments have been about the 23.7% of the total with judgments ranging from *tiring, alienating, but also very comfortable. I wouldn't want to give up* to *I felt the joy of meeting the students* and *finally some digital.*

5.3 Teachers' Digital Competence Belief

Department of Humanities teachers had a high level of institutional support for introducing technology into education. To encourage and enhance university teachers' technology acceptance, University Federico II of Naples has offered many proposals, as a Learning Management System project to co-create a mobile educational path for university digital education. iMILK Innovative Mobile Interactive Learning and Knowledge [35] has been designed to co-create a Learning Management System for university mobile education.

Despite institutional support, results show uncertainty, traditionalism, caution, and mistrust towards the introduction of technology in education. A possible hypothesis could be that contextual facilities aren't the only key point to support teachers' adoption of technology [27].

Two other issues are intertwined to explain teachers' behavior. One is the related to their own beliefs about their digital competencies. If teachers believe not to be enough good to introduce technology in education, they will reduce their efforts and be discouraged. Perceived self-efficacy – named Teachers' Digital Competence Belief (TDCB) – and motivation, together with teachers' knowledge, skills, and attitudes, can play a key role in influencing teachers' intention to use technology in teaching and learning processes more than contextual facilities.

5.4 Work in Progress

This research shows the role of teachers' self-efficacy in developing their own digital competencies. Future research should explore the possible enhancement of teachers' digital competencies after the implementation of University courses designed to strengthen teachers' self-efficacy in digital educational world.

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Differences in the Comprehension of the Limit Concept Between Prospective Mathematics Teachers and Managerial Mathematicians During Online Teaching

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Abstract. The paper deals with university student's understanding of a limit process. We involved two groups of students with different specializations in the research: a group of pre-service mathematics teachers (PMTs) and a group of students of managerial mathematics (MNGs). Since the objectives for learning higher mathematics, particularly mathematical analysis, differ significantly, we expected a significant difference in reasoning between these groups. Therefore, we identified (literature- and empirical-based) the most common obstacles and misconceptions when learning a concept of limit. A teaching series was prepared, enacted, and analyzed. When analyzing students' solutions, we applied codes from the literature with minor changes. We used two-dimensional contextual analysis to work with students' answers and provided explanations: type of argument (based on Stylianides's work) and representation. Our findings confirm the problems identified in the literature when we looked at the groups without distinguishing them. Moreover, we identified and discussed some specific outcomes in the group of PMTs and MNGs separately.

Keywords: teaching and learning calculus · online learning environment · understanding limit process · COVID-19 effect on teaching calculus · interactivity during online teaching

1 Introduction

Mathematical analysis (at least on the basic level) is intertwined through all STEM-oriented university studies. It is a critical milestone in various transition processes from secondary school to university mathematics. For many students it is "the necessary evil" to pass through, and many of them struggle in their courses. One reason of this struggling could be the huge difficulty of linking between the knowledge of mathematics learned at university and the knowledge acquired in secondary school. This gap between mathematical levels and institutional cultures can lead to several study problems of freshmen.

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As Pinkernell [1] summarizes, students meet different level of rigor in communication or reasoning, and institutional differences, e.g., concerning the didactic of teaching and learning mathematics. The other problem could be that situation at some study programs is almost the same as one of the interviewees said in research made by Bosch et al. [2], "…the exercises is a list that comes from father to son. It's the same list that has been there for the past 10 years. […] the key for 60% or 70% of the students to pass is to do an exam that is not essentially different from previous one". Critical reason could be also that many students are only passive listener and users of calculus. The algorithmic characteristic of the tasks solved in the lessons and tests can lead to passing through exams without deeper understanding on subject matter. In terminology of Boaler and Andrew-Larson [3], most of our students have "received knowing", which means, they believe that doing mathematics means to memorize and quickly recall information needed.

2 Objectives and Literature Review

Limit concept appeared in early times especially in connection with determining the measure of shapes with curvilinear sides (for example, Archimedes used this concept to calculate the area of the circle and measures of another shapes and solids). A similar use of the limit process also appears in the works of mathematicians of the 17th century (e.g., Kepler, Cavalieri), the use of limit concept with the current meaning of derivative we can find in works of Descartes and Fermat. Dutch engineer Simon Stevin and Italian mathematician Luca Valerio use the concept of limits to replace the need for a double reductio ab absurdum in the ancient Greek method of exhaustion. It was only about 150 years later that the rigorous definition of the limit was constructed through the works of Cauchy and Weierstrass [4]. Cauchy build on d'Alembert understanding of the limit concept and used this notation in defining of concepts as derivative and continuity. He used infinitesimally small quantity with sufficient refine as a variable with zero limit [5, 6]. Weierstrass substituted dynamical concept of the limit based on the phrases like "approaches" or "arbitrarily close" with static one, which is known as "epsilon-delta" definition of limit. The definition (1) is one of the most common definitions of the limit which students at the STEM-oriented universities are comping with (also called "epsilon-delta" definition)

$$\lim_{x \to a} a_n = L \Leftrightarrow \forall \varepsilon > 0\ \exists \delta > 0\ |x - a| < \delta \Rightarrow\ |f(x) - L| < \varepsilon \tag{1}$$

Students' understanding to the formal definition (1) requires students to decode its meaning from a relatively complex symbolic statement. A slight change in the wording of the definition brings a great change in its mathematical content. Many students do not notice it.

Using the limit concept other fundamental concepts like continuity, differentiability and integrability are all established. The misinterpretation or incorrect using causes later problems, as shown on Fig. 1.

There are several closely related and derived concepts in differential and integral calculus, series, etc. As studies (e.g., [8–13]) or the practical experiences of educators confirm, students can master many formalized rules and computational algorithms of

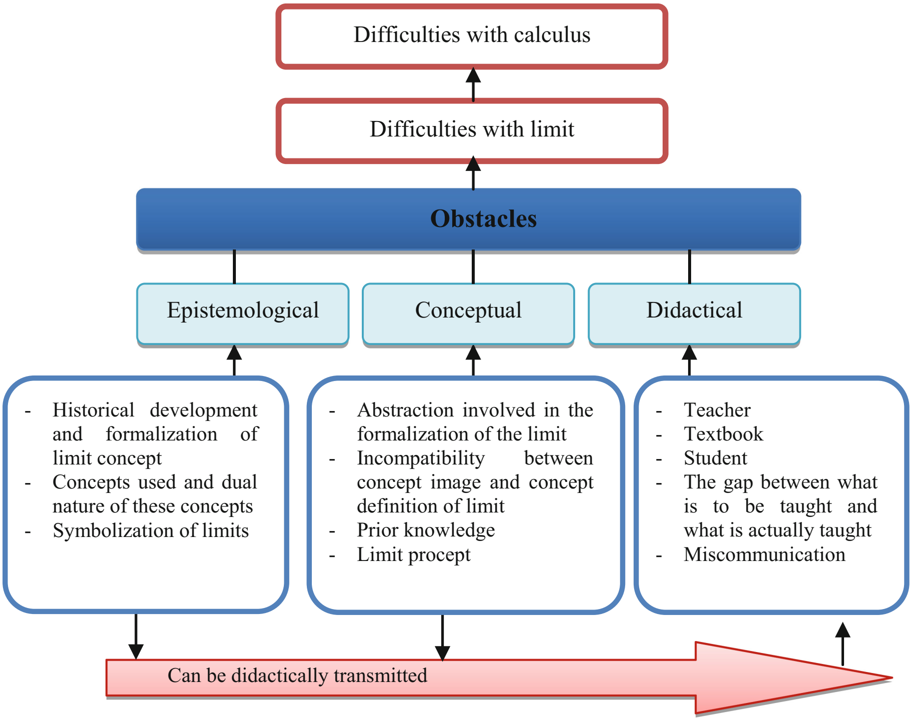

Fig. 1. Representation of limit-related obstacles (source: [7])

mathematical analysis, but at the same time a deeper understanding of the problem (conceptual understanding) may not occur.

Most studies dealing with the mentioned problem states the well-known fact that understanding the concept of limit causes students' considerable problems (e.g., [9, 14–18]). Williams [15] even claims that a complete understanding of the concept of limit is very rare even in the case of students in the first two years of university studies. Indeed, Williams [15] agrees with the opinion of Ervynck [14] that most students will not fully understand the concept of limit even after completing a calculus course (either in the case of limits of a sequence or limits of a function) and their idea of this concept does not correspond to the formal definition of limits. A similar conclusion was reached by Bastürk and Dönmez [19], who investigated the understanding of the concept of limits among pre-service teachers.

Cornu [16] pointing on that a limit concept is the first topic in which students meet infinity, or infinitesimal process in explicit form. Orton [20] declare that students understand infinity as extremely big number. Consequence of this understanding is using symbol ∞ as representant of variable or notation of number (as in algebra). Sierpinska [11] observed the same phenomenon, when students use the analogy: "since $\frac{k}{k} = 1, k \in N$ then $\frac{\infty}{\infty} = 1.$"

Based on our previous research, [21], freshmen are struggling with basic properties of functions (mostly goniometric and logarithmic), have no experiences with formal mathematical notation and therefore are not able to follow the lectures. Moreover, they have problems with logical structure of statements containing several quantifiers and lack experience with rigor in reasoning. Therefore, in our research we focused on connected knowledge in terms of reasoning and proof in the two groups of students with different study programs at Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, Slovakia.

3 Methodology

3.1 The Sample and Stating of the Research Questions

We have chosen two groups of students: pre-service mathematics teachers (PMTs) and group of managerial mathematics students (MNGs). In the Table 1 are the characteristics of the groups.

Table 1. Group characteristics.

	PMTs group	MNGs group
Number of students	24	28
Expected knowledge	Basic knowledge of mathematical disciplines with the aim on overview of mathematics from higher level	Extensive knowledge of mathematical disciplines focusses on applicability in the field of management, economy, and finance
Expected outcome	Conceptual understanding	Procedural fluency (with conceptual understanding)
Goal of the study program	Knowledge about how to express math ideas using mathematical language and symbolism	Mathematical modelling (in context of management, economy, and finance)
Lessons per week	2 (lectures)/2 (practical)	4 (lectures)/4 (practical)

As can be observed in Table 1, there are different expected knowledge, outcomes (based on [22]) and goals of the study program. While for PMTs the course of higher mathematics is kind of superstructure over the high-school mathematics, for MNGs it is a tool for modelling. And this is what influenced all the activities on the lessons when working with these groups.

We observed the lessons with changed approach to teaching a limit process and tested two groups of students at our faculty on comprehension of the definition of a limit of a sequence (how can small changes, e.g., order in quantifiers, in definition of specific concept influence the meaning of the definition) through ability to give a valid argument, justification.

When analyzing the students' solutions, we kept in mind our research question: *How the ways of reasoning in the groups of PMTs and MNGs differ when teaching/learning in online environment?*

3.2 Preparation and Learning Phase: Lessons Descriptions

Due to COVID-19 lessons had to be shift into online environment. We were aware of the fact, that for first-semester mathematical analysis students the notion of limit is key and, at the same time, the most difficult concept to grasp. This concept needs students to overcome significant cognitive obstacles, which are necessary to understand fully the classic "$\varepsilon - n$" (the simpler case) or "$\varepsilon - \delta$" definition of a limit.

When designing the teaching sequence focused on sequence convergence, we understood the students' need for numerous experiences with infinite sequences to be able systematically to mathematize their experiences and developed mental schemas for classifying given sequences as eighter convergent or divergent. With the students, we discussed various real situations in which the limit process can be used (e.g., the level of the drug in the patient's blood for a long time, finding the circumference of a circle, etc.).

We provided and encouraged the students to work with geometrical representations of the limit process [23] or a graphic representation of the definition of limits of sequence (ε -stripes) by using digital technology (Fig. 2) and observe how and why the formal definition works. To eliminate the most common misconceptions concerning a limit of a sequence, we provided a set of examples that were (in most cases) in contradiction with students' prior incorrect understanding of this notion.

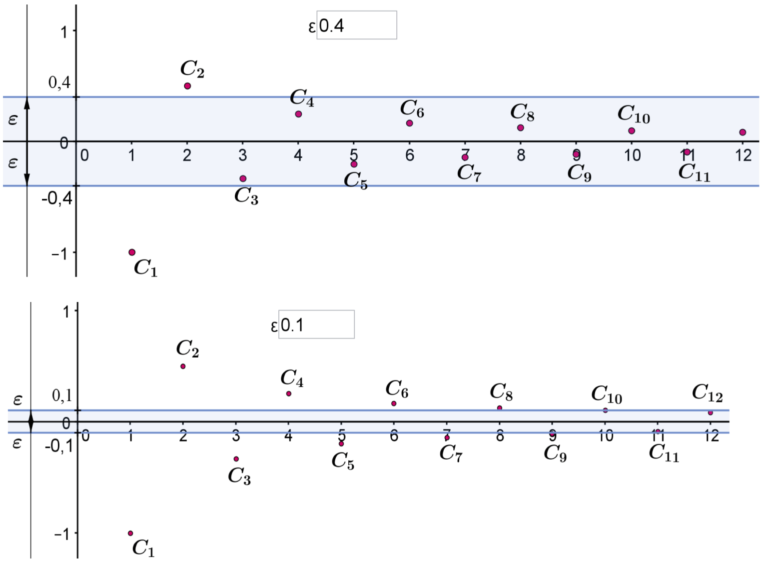

Fig. 2. Epsilon stripes for specific values of ε

For example, by utilization of divergent sequence $\{a_n\}_{n=1}^{\infty} \equiv \left\{-\frac{1}{2}, \frac{1}{n}\right\}_{n=1}^{\infty}$ students could realize that to describe the behavior of the convergent sequence is necessary universal quantification of ε, upon which n_0 is dependent and not vice- versa (Fig. 3).

In the next two examples we are providing some epistemological obstacles we tried to avoid when working with limits on the lessons.

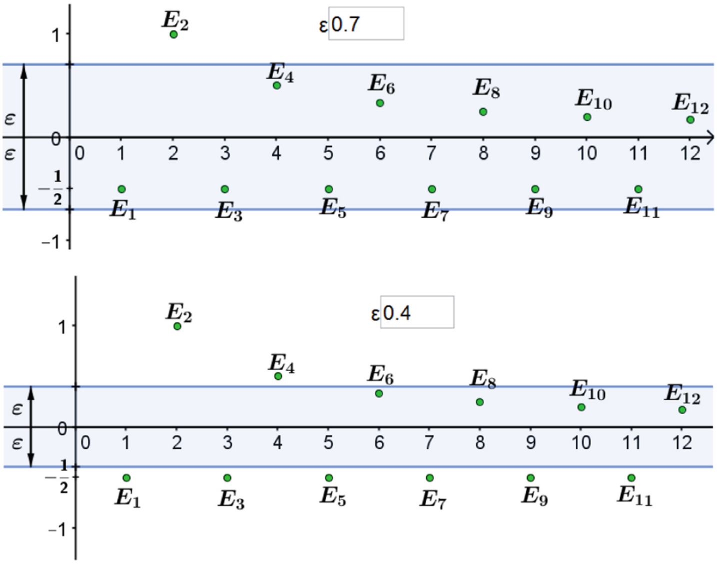

Fig. 3. Epsilon stripes used on divergent sequence $\{\boldsymbol{a_n}\}_{\boldsymbol{n}=1}^{\infty} \equiv \left\{\frac{1}{2}, \frac{1}{\boldsymbol{n}}\right\}_{\boldsymbol{n}=1}^{\infty}$

Limit as an Asymptote

The student's interpretation is based on idea that terms are closer to specific value from one direction, but never reach or overleap it. To contradict students' misconception, or to avoid it, we can use, for example, the sequence $\left\{\frac{1}{n} + \frac{(-1)^n}{n}\right\}_{n=1}^{\infty}$ (Fig. 4). This sequence can be in contradiction with students' incorrect prior concept and rephrasing the definition in a sense like "the terms of sequence $\{a_n\}_{n=1}^{\infty}$ are closer and closer to its limit L when n is bigger, but they never reach L".

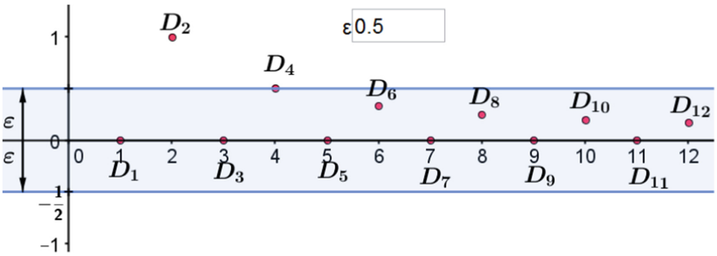

Fig. 4. Graphical representation of sequence $\left\{\frac{1}{n} + \frac{(-1)^n}{n}\right\}_{n=1}^{\infty}$

In the context of monotone bounded sequence, we discussed with the students whether the following statement is correct: "Number L is called the limit of a sequence $\{a_n\}_{n=1}^{\infty}$ if its terms are closer and closer to the number L when n is bigger."

Consequently, we discussed with students whether condition $L - a_n > L - a_{n+1}$ (in the case of sequence increasing and bounded above) for every $n \in N$; $n > n_0$, uniquely determines the only number L, that is limit of that sequence.

Limit as Accumulation Point of Sequence

In the meaning when students change the correct definition of limit of sequence with following statement: Real number L is called the limit of a sequence $\{a_n\}_{n=1}^{\infty}$ if for every $\varepsilon > 0$ there exist an $n_0 \in \mathbb{N}$ such that $|a_n - L| < \varepsilon$ for infinitely many $n > n_0$.

Even in this case can be the previously mentioned sequence $\{\boldsymbol{a_n}\}_{\boldsymbol{n}=1}^{\infty} \equiv \left\{\frac{1}{2}, \frac{1}{\boldsymbol{n}}\right\}_{\boldsymbol{n}=1}^{\infty}$ (Fig. 3) create cognitive dissonance in the student's mind as it could lead to understanding that his prior concept is incorrect.

3.3 Testing Phase

In the test we focused on the type of argument elicited (in terms of Bieda et al. [24]), different types of arguments (empirical argument, counterexample, formal proof, etc.) and using different representations (e.g., graphical, symbolical, verbal, etc.).

We gave students in both groups the test a semester later from two reasons:

1. To find out whether their knowledge is connected in a sense of [3] (in other words, we wanted to prevent using recitation of the formulas without understanding)
2. To see the effect of online teaching during the pandemic COVID-19

Both groups of students were given the same test with tasks like the ones we worked with and discussed. The test comprises one task focus on justification claims, more specific on decision which claim is equivalent to the (well know) definition of a limit of sequence. The chosen task for the students was as follow:

Which of the following formulations is equivalent to the correct definition of the sequence limit? Justify your statement in detail (indicate which part of the statement contradicts the formal definition or give an example that points to this contradiction).

a) A real number $a \in \mathbb{R}$ is a limit of a sequence $\{a_n\}_{n=1}^{\infty}$ if and only if for every real number $\varepsilon > 0$ exists finite subset $\mathcal{M} \subset \mathbb{N}$ so for every $n \in \mathbb{N} \backslash \mathcal{M}$ stands $|a_n - a| < \varepsilon$.
b) A real number $b \in \mathbb{R}$ is a limit of sequence $\{b_n\}_{n=1}^{\infty}$ if and only if for every real number $\varepsilon > 0$ exists natural number $n_0 \in \mathbb{N}$, so for infinitely many $n > n_0$, $n \in \mathbb{N}$, $n \in \mathbb{N}$ stands $|b_n - b| < \varepsilon$.
c) A real number $c \in \mathbb{R}$ is a limit of sequence $\{c_n\}_{n=1}^{\infty}$ if and only if there exists such real number $\varepsilon > 0$, so for every natural $n > n_0$, $n \in \mathbb{N}$ stands $|c_n - c| < \varepsilon$.

Students had 20 min to decide these three "definitions" and support their decision with arguments, justification. Since we postpone the testing phase in one semester, the test was written in the classroom (face-to-face lesson).

3.4 Analysis of the Obtained Data

When analyzing the students' solutions, we kept in mind our research question: *How the ways of reasoning in the groups of PMTs and MNGs differ when teaching/learning in online environment?*

We used adjusted framework based on Bieda et al. [24] and Stylianides [25] to create categories for different solving strategies. Since we tested only "justifying claims" (in terms of Bieda et al. [24]), the adjusted framework had the structure presented in Fig. 5.

Empirical argument is an argument that provides inconclusive evidence for the truth of mathematical claim (similar to [26] "empirical justification" and [27] "naive empiricism"). *Rationale* - capture arguments for or against mathematical claim that are neither proofs nor empirical; "transition between empirical reasoning and proof-type reasoning." This type of argumentation is not sufficient in mathematics.

Generic example is an argument that uses a particular case seen as representative of general case (similar to [26] "transformational proof"). *Demonstration*, according to [25], this term represents argument does not rely on the representatives of particular case (similar to [26], "axiomatic proof" and [27], "thought experiment"). This includes valid deductive arguments by counterexample, contradiction, mathematical induction, contraposition, exhaustion, etc.

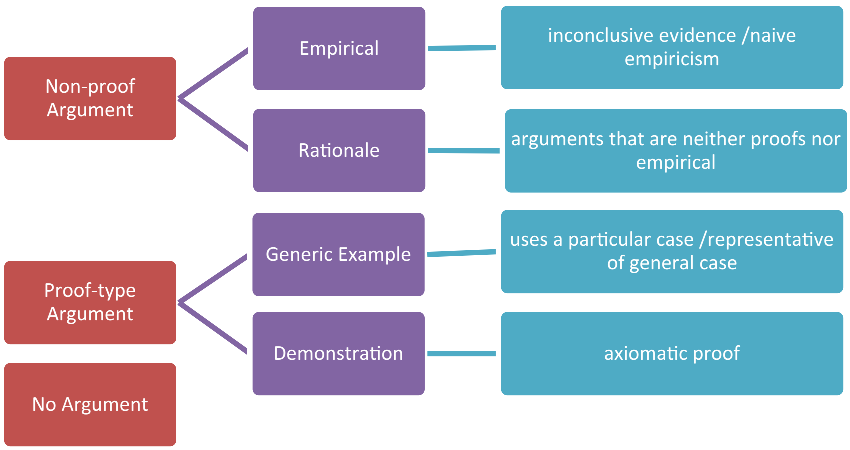

Fig. 5. Adjusted frameworks used for the analysis of students' solutions in justifying claims

We divided solutions into the groups with the same characteristic according to the used argument, in the following phase we made subgroups based on the representation used, like presented in Table 2.

For each category in the first 2 columns there are 5 different representations to be used by students when solving the tasks. Therefore, we expected 5 groups and 5 subgroups for each group.

Table 2. Expected students' solution strategies.

Argument type	Additional type of given argument	Used representation
1. Non-proof	empirical	a. algebraic b. figural c. verbal d. switch between representations e. other
	rationale	
2. Proof	counterexample	
	demonstration	
3. no argument		

4 Results and Discussion

4.1 Pre-service Mathematics Teachers Group Results

When analyzing the solutions of PMTs, we identified several types of justifications, or explanations of their thinking (see Appendix 1). In that summary, we did not distinguish correctness or incorrectness of the provided solution by PMTs. Since we looked for every PMTs and each part (a-c) on the type of argument and representation, the sum of the numbers in the Appendix 1 is tripled.

Looking on the correctness of the solution and provided arguments, there were only 3 students who answered correctly (that option "a" is an equivalent definition to the original one and provided counterexamples to the options b and c. In the rest of the group, we identified epistemological obstacle "limit as an accumulation point", two conceptual obstacles: (i) overgeneralization, when students manipulated with infinite sets like with finite sets, and (ii) use/understood "for infinitely many" as equivalent of "for all" (see Fig. 6, answer b).

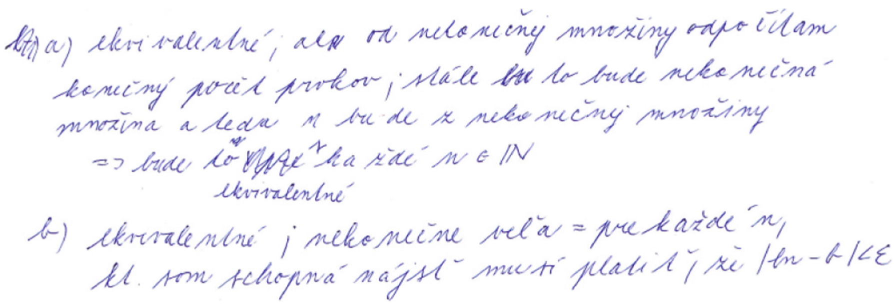

Fig. 6. Example of PMT solution [translation: a) equivalent, if we subtract finite number of members from infinite set, this set remains infinite, therefore n belongs to the infinite set => it will be equivalent for any natural n] [translation: b) equivalent; infinitely many = for any n, which I can find must stands $|b_n - b| < \varepsilon$]

Since we try to prevent the last-mentioned misconception (ii) during classes, by providing a set of examples and tasks that could be in contradiction with PMTs prior concept, our findings showed how durable and resistant this misconception is. PMTs used mostly proof-type arguments with algebraic and verbal representation for their arguments, or switch between algebraic, verbal and symbolic.

4.2 Managerial Mathematics Students Group Results

In the case of MNGs students, the results were similar, deductive arguments by counterexample or attempt to produce generic example prevailed among them as well. Summary of MNGs working is in Appendix 2.

Looking on a correctness of MNGs justification, only one student correctly identified formulation equivalent with proper definition of limit of sequence and correctly reasoned why the remaining two formulations are not equivalent. The remaining students marked as the correct answer formulation option b (Fig. 7) with very similar misconceptions as were identified in group of PMTs. The case in Fig. 7 points on use/understood "for infinitely many" as equivalent of "for all".

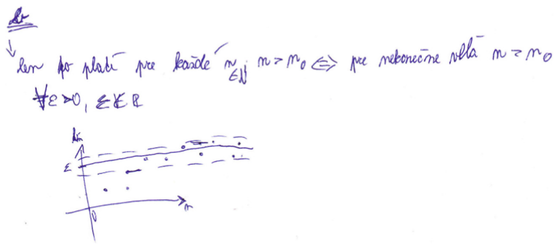

Fig. 7. Example of MNG's argument [Translation of the text: b [is correct] but it works for every natural $n \in \mathbb{N}$, $n > n_0 \Leftrightarrow$ for infinitely many $n > n_0$, for any real $\varepsilon > 0$]

In many cases was clearly identified memorized second part of the definition (Fig. 8) This phenomenon is often observe in students on applied study programs not only by us.

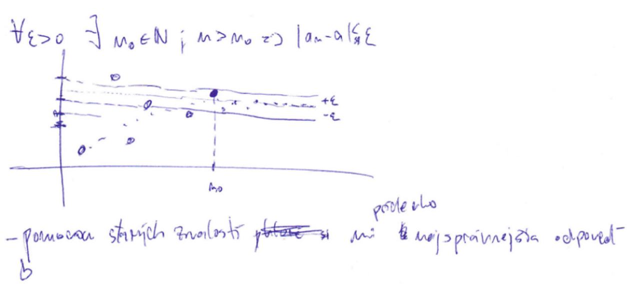

Fig. 8. Example of imitating reasoning [translation: I use the old knowledge to find out the correct solution – b]

In both examples in Fig. 7, and Fig. 8 are visible imitating what was done on the lessons (e.g., epsion-stripes, remembered part of the formula) besides the described misconceptions. MNGs used also proof-type arguments but mostly figural representations of their arguments or switch between figural and verbal.

4.3 Discussion

Several studies (e.g., [15, 28, 29]) confirm our results and experiences. The limit concept is difficult to students since statical definition of the limit (sequence or function) is in contradiction with their intuitive dynamic understanding of this process. When describing a limit process or reading symbolical representation ($\lim_{n\to\infty} a_n = L$, $\lim_{x\to a} f(x) = L$), students use expressions like "with bigger n sequence members are closer to number L", "when x approaches to a values of the function f are infinitesimally close to the value L". These expressions have a dynamical character.

As we observed, transformation of dynamic form of the limit to the statics symbolic expression using quantifiers could be challenging for students in both groups. Several misconceptions were identified. The most common were epistemological obstacles, when students applied properties of finite sets to the infinite ones (as described in [8]), problems caused by fundamental linguistic flaws in the standard presentation of limit (as identified in [4]) and misunderstanding of the quantifier logic in mathematical statements.

Students often use imitative reasoning, e.g., copy algorithms or recall facts, when solving mathematical tasks [30]. As we demonstrated in Fig. 8, students memorize the formula as a picture without deeper understanding it.

The data were collected at a time when the students were already familiar with the terms and concepts defined using the term sequence limit, or functions (derivative of a function, a definite integral, the sum of an infinite series). Our findings show that if the basic concept is not correctly understood, additional mathematical superstructure and more experience with the mentioned concepts do not guarantee that there will be a correction and a deeper understanding of the basic concepts (e.g., [31]) Also, for this reason, it would be worth considering devoting a certain amount of time so that students arrive at the formulation of the correct definition of limits on their own with the help of guided research.

Some problems could be caused by online teaching due to the COVID-19 pandemic. Missing spontaneous discussion between teacher and students when working with new concepts, instant feedback from facial students expressions, and lack of peer interaction outside the classroom were the most common problems we observed. On the one hand, students appreciated that lessons (both lectures and practical) were recorded, so they could watch them again when they missed something. On the other hand, PMTs and MNGs pointed to missing group learning in dormitories or study rooms.

5 Conclusion

Even though two studied groups of students had different backgrounds and mathematical training at the university, there are no significant qualitative differences between these groups when answering our questions. On the other hand, we observed higher effort to reason and prove the answers in the group of MNGs.

The most common argument in both groups was by providing a counterexample. Although students during the semester encountered several different representations of sequences and their limit (graphical, algebraical, numerical, topological), the most popular way of solving the tasks was figural, by using epsilon stripes.

We observed no significant differences between the groups, therefore, more targeted lessons are needed. Lessons should be more connected to the practice (e.g., economy, sciences), this implies cooperation among different departments (mathematics, sciences,…), which can help to provide a set of examples that will be in contradiction with student prior understanding of the problematic's notion.

The second outcome is that working on deeper understanding of mathematical notation and language is needed. Students on lower levels should work more with quantifiers, changes in order or type etc. Tasks (from the lowest grades) should be focus on "making and justifying claims" (not only on justifying),

Identified obstacles are mostly epistemological (accumulation point) and conceptual (overgeneralization, misunderstanding of the concept itself). Most of the students usually memorize definitions without fully understanding them. The biggest and resisted problem in mathematical analysis observed in both groups of students was incorrect equivalence: "for infinitely many" = "for all".

All of mentioned problems could lead to didactical obstacles, when (especially) PMTs may misinterpret the role of mathematics, importance of reasoning and proof tasks, and most importantly their teaching style could be negatively influenced, and the problem could be even worse in next 10 years.

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Appendix 1

(See Table 3)

Table 3. Used type of arguments and representations by PMTs

Type of used argument	Used representation	Subtask	Number of PMTs
No argument		a	1
		b	4
		c	–
Non-proof: rationale	switch between algebraic and verbal	a	2
		b	3
		c	1
	verbal	a	2
		b	1
		c	1
Non-proof: empirical	switch between algebraic and verbal	a	0
		b	0
		c	1
Proof: counterexample	algebraic	a	0
		b	1
		c	9
	figural	a	0
		b	2
		c	1
Proof: demonstration	verbal	a	6
		b	1
		c	4
	switch between algebraic, verbal, and figural	a	1
		b	4
		c	1

Appendix 2

(See Table 4)

Table 4. Used type of arguments and representations by MNGs

Type of used argument	Used representation	Subtask	Number of MNGs
No argument		a	3
		b	4
		c	1
Non-proof: rationale	switch between algebraic and verbal	a	4
		b	5
		c	1
	switch between figural and verbal	a	4
		b	6
		c	1
Non-proof: empirical	switch between algebraic and verbal	–	–
Proof: counterexample	algebraic	a	0
		b	2
		c	13
	verbal	a	4
		b	0
		c	2
Proof: demonstration	verbal	a	2
		b	5
		c	1
	switch between algebraic, verbal, and figural	a	5
		b	6
		c	2

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Students' Difficulties with Mathematics: Insights from Secondary-Tertiary Transition in a STEM Program

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Abstract. Drop out during the first year at university STEM courses is a plague spreading all around the world and research in Mathematics Education revealed that mathematics is one of its main causes: not only the students' mathematical knowledge, but also affective issues such as attitudes towards learning mathematics, views about mathematics itself, as well as emotions determine the students' success or failure in university career. We investigate the intertwining of cognitive and affective dimensions in freshmen Engineering students attending a bridge course in mathematics at the beginning of the first semester at the Politecnico di Milano.

Keywords: Engineering students · Quantitative nonparametric methods of data analysis · Blended learning · Secondary-tertiary transition · Difficulties in mathematics · Affect-related variables in mathematics education

1 Introduction

Every year, at the beginning of the first semester, in universities all over the world, thousands and thousands of freshmen enrolled at STEM university courses come to attend their first lessons. We know that around 40% of them would not sit in the same classroom a few months later, because of dropout. What kind of information can we get from these first days at university, which can help universities to reduce dropout? In this paper, we aim at contributing to this big, overarching question by: firstly, recalling the main findings concerning mathematics difficulties at first year STEM university courses; and secondly, focusing on the factors that have revealed to be central to understand the issue, and, thus,

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relevant to intervene on dropout. Using regression trees and community analysis, we aim at identifying sub-groups of students (we will call them "profiles") who need differentiated interventions.

The phenomenon of STEM-related dropout has received increasing attention in the literature. In [23], a theory of academic persistence is proposed that is of inspiration for subsequent studies, since students' persistence is affected by a number of factors, as skills, abilities, and prior schooling, as well as by experiences at university. In [16] it is stressed that students should adjust to a new context, a new program, new teaching practices, and a new institution, and different variables that should be considered to understand students' adjustment in the school-university transition are proposed. Among them, gender, students' expectations, coping strategies and school of provenience are the most relevant.

University mathematics, in particular, causes difficulties to students with STEM majors in general and to Engineering students in particular [11]. These difficulties can be traced back to several aspects that generally concern differences between secondary school and university [12]: from the different university courses organization [13] to the different thinking modes that are required at university. In a fundamental study, [5], it is contended that, at the basis of the leap between secondary and tertiary studies, there is a shock *from procedural mathematics to conceptual understanding that university mathematics entails*. For such a reason, it is strongly suggested that transition should be smooth, and communication between school and university should be improved [5]. According to this view, universities from almost all over the world offer preparatory courses whose goal is to bridge the gaps between school and university, supporting freshmen students to recapitulate certain mathematical topics. In the sequel, we name them "Bridge Courses".

The focus of this paper is on sub-groups of students who may find the transition more difficult, compared to their mates. The differences in mathematical attainments between groups of students, and across schools, is a topic of crucial interest for both educators and policy-makers (see e.g. [19]). In the sequel, we briefly recall the main findings to this regard.

Gender Issues. There is an increasing number of studies focusing on the crucial role of social and affective factors, besides the cognitive ones, in undergraduate mathematics learning. [19], for example, underlies that the students' features –such as gender and attitude towards study– influence students' attainment. In particular, it is well acknowledged that women are under-represented in STEM disciplines (see e.g., [8]) and we refer to the model introduced in [7] to capture stability and flexibility of gender differences in social behaviour. This model is social and psychological in its roots and takes into account both the social influences on boys and girls enrolled in STEM courses, and inner disposition.

Mathematical Backgrounds. Students' views of mathematics take also a key role. The study reported in [22] has for us many sources of interest. First of all, it discusses from a theoretical point of view the concept of "views of mathematics" and the related concept of "beliefs about mathematics". The authors state that "students' beliefs, wants and feelings are part of their view of mathematics".

Secondly, the authors argue about the key role of different school backgrounds, different math curricula and different views and expectations in freshmen students attending a Bridge Course. Within this perspective, the role of beliefs (about mathematics) is crucial in determining university success or failure [1,6]. Specific to the Italian context, [17] has proved that the kind of high school influences both cognitive and affective factors in the transition. Also [19] proved that school-level characteristics influence the students' mathematical performances: however, they focused on single schools features such as their size, their Dean's views and management practices, while in our study we focus on the kind of mathematics the students experience at school. In fact, in the Italian context, students who enroll in STEM courses mostly come from three kinds of secondary school: scientific (LS), humanistic (HU), and technical (TE). LS is a type of secondary school with a strong curriculum in math and sciences, while HU is stronger in history, philosophy, languages and arts. And, while LS and HU curricula are specifically designed to prepare students to go to university, TE curriculum is mostly related to workplace, but it is not rare that students from this type of school enroll at university. A focus of this sort [1,17] allows us to understand the role that both mathematical prerequisites (at cognitive level), and views about the importance of mathematics in real life (mirrored by the importance assigned to mathematics in each school type's curriculum) may play in the transition to university STEM courses.

The Digital Turn. The last factor we consider is related to distance learning and e-learning in general. In particular, the students' disposition toward on line teaching material plays a key role in our study, given the organisation of the Bridge Course under investigation. More generally, this factor is related to differences between conceptual and procedural aspects in mathematics, as we argue in the following. Some researchers (e.g. [10]) found that teacher-centred (or teacher-oriented) methods (TO) favour the development of procedural knowledge, while student-centered (or student-oriented) methods (SO) favour the development of conceptual knowledge. A TO lesson provides the students with a linear and organised exposition of knowledge, while a SO one engages students in group-work activities, classroom discussions and in the production of meanings that are inevitably other than final or "authorized", they are personal and provisional, not universal and absolute. A Massive Open Online Course (MOOC) has a SO pedagogical format, in that the students are required to: (a) watch videos and get sense of their content (without any guidance from the teacher); (b) in case parts of the videos are not clear for the student, search for other sources in order to make sense of the content; (c) make interactive exercises and, in some cases, engage in forum discussions. All this entails a production of meanings that is personal and that emerges from the mathematical activity in which the student is engaged. MOOCs are becoming a teaching format common to many universities all over the world. Also the Bridge Course under study takes on a blended learning format, as we will detail more in the section dedicated to the context of the research.

2 The Context of the Research

The Bridge Course, delivered every year at the Politecnico di Milano[1], is a preparatory course before the beginning of the first semester. The Bridge Course recapitulates the basic math knowledge learned at school and is made of an e-Learning part and an attendance part. Students who enroll at university are invited to attend the MOOC course before the attendance one. In the e-learning part, the students are asked to recap essential mathematics on Pre-Calculus MOOC on POK platform (www.pok.polimi.it), where they can watch videos on theory and exercises, and assess their basic knowledge in mathematics through quizzes. In addition, they can interact in a forum. The MOOC course is structured in 6 learning weeks, one for each of the following topics: arithmetics, algebra, geometry, logics, functions, probability. The in-presence part features the students in SO activities, such as group work activity and discussions built upon the syllabus of the Pre-Calculus MOOC. The attendance part consists in 32 h of lessons, spread in the first 2 weeks of September.

We maintain that the Bridge Course combines self-directed (i.e., MOOC) and externally-regulated (i.e., attendance) learning types of instructional formats. There's a need for the latter, since learners are new at the university, they have to acclimatise with the new learning environment and attendance helps them to familiarize with the new didactical contract and the new organisation of courses [21]. There's a need for the former, since learners at university have to be more self-directed and e-Learning helps to adapt their learning behaviour [18].

The data for this study come from a questionnaire, administered at the end of the in-presence part, which investigates affective factors, and from four tests, which assess the students' knowledge on algebra, geometry and logics, calculus, and probability and statistics.

The questionnaire (referred to as Q) is composed by two main sections: 1) the personal data (Q0 in the sequel), and 2) the affective section (QA). Q0 asked about: gender, school type and MOOC attendance. QA is made of 6 questions. Question QA.1 asked whether students faced new math topics in the Bridge Course, while Question QA.2 asked whether they saw exercises or problems formulated in a different way. QA.3 opens a window on the students' expectations about math at the university and QA.4 investigates whether the students have been exposed to SO learning formats at school. QA.5 and QA.6 were dedicated to MOOC/course appreciation and aimed at investigating the students' disposition toward e-learning materials.

The math tests, made up of 10 multiple-choice questions each, provide information about the students' mathematical knowledge and skills. They have been administered on the second day of the attendance course (algebra), on the fourth one (geometry and logics), on the sixth one (calculus), and on the eight and last one (probability and statistics).

[1] Politecnico di Milano is the technical university of Milan with Engineering, Architectural and Designer programs.

3 Theoretical Background

The type of data that we would like to analyse are heterogeneous. Indeed, we have both quantitative variables measuring students' performances, and qualitative ones related to personal-level features and affective aspects. Moreover, there is a plea in Mathematics Education research for studies that do not assume linear correlations between variables that are complex in nature. This is especially true when affective aspects are under scrutiny.

For these reasons, we resort to methods that do not rely on strong modelistic assumptions on the structure of data, nor on linearity of connections. We employ classification trees to investigate the influence of personal-level features (i.e., gender, school type, and MOOC attendance) on mathematical test performances. We recall that previous studies in Mathematics Education have resorted to classification trees to investigate the interplay of cognitive and affective factors in determining students' performances [1].

Parallel to classification trees, in order to identify how students clusterize when they expose their views of mathematics, we resort to network analysis and, specifically, to community detection, a novelty in the educational context [14]. One can wonder whether a more classical unsupervised clustering method was not employed for this purpose. We argue that in qualitative questionnaires the strong limitation of the latter approach is the need of defining a suitable metric to measure differences between students' answers, which can be avoided using a network analysis approach. In the following the two methods are described in detail.

Regression Trees. The regression trees is a method that aims at predicting the value of a numerical target variable on the basis of several input variables, and selecting the input variables that explain the most the target variable. For the analysis presented in this paper, we will use the tree for predicting the students' score in the math tests. Specifically, a tree T is a set of successive splits that group the initial set into C groups, corresponding to the *leaves* of T. A tree is constructed by computing, for each factor to be considered, the information gain (with respect to the target variable) given by splitting the initial population into two groups, using some threshold value of the input variables. In the case of regression trees, the gain is computed as the amount of variance reduction of a split. Every possible split in terms of the input variables lead to a division of the sample units into two separate groups (i.e., their intersection is empty). For growing the tree, an iterative algorithm is used. The algorithm starts with a tree with a single node and successively splits it exploring all possible splits and performing the one that most reduces the variance (see [9]).

Network Analysis. Regression trees allow us to examine the relationship between the students' performance on tests (i.e., a measure of cognitive aspects) and personal characteristics of the students such as gender, school type and MOOC attendance. But we need a different mathematical tool to identify clusters within the set of students who answered the questionnaire Q, which represent a very big and complex set of data. Since the data are qualitative and not quantitative we decided to use the *community analysis*. Community analysis reveals possible sub-networks (i.e., groups of nodes called communities, or clusters, or modules) characterised by comparatively large internal connectivity, namely the nodes that tend to connect much more with the other nodes of the group than with the rest of the network [4].

Hence, we use community analysis to recognise clusters of students and figure out students' profiles according to their attitudes. To that end, a students' network is designed for the set of answers to Q. The method proposed by [4] is used to design the network, where two nodes are linked if they co-participate at the same 'meeting'. In this work, the nodes of the network are the students while the 'meetings' are represented by the same answer to the questions of the affective section QA: the more answers they have in common the stronger the link between two nodes. For example, if students i and j gave 8 same responses to the questionnaire (i.e., select the same items), hence there exists a link between nodes i and j, and its weight is 8. Figure 1 exemplifies such an idea. The personal data collected in Q0 represent further attributes of the nodes. As a consequence of this approach, the network (N in the following) is undirected and weighted.

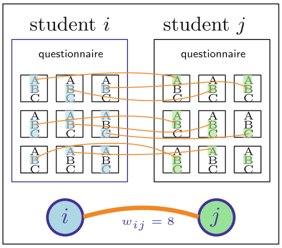

Fig. 1. Schema for the design of students' network: students i and j gave 8 same responses to the questionnaire, hence there exists a link between nodes i and j, and its weight is 8.

Since we are interested in identifying sub-networks of students according to their attitudes, we seek for a specific partition of the set of nodes induced by a certain measurable quantity. To that end, we adopt the so-called "Louvain method" [3] based on the optimization of the *modularity* Q. Roughly speaking, given a partition $\{C_1, C_2, \ldots, C_K\}$ of the network, modularity Q is the (normalized) difference between the total weight of links internal to the sub-graphs C_k, and the expected value of such a total weight in a randomized "null network model" suitably defined [20]. To evaluate the goodness or triviality of each community we adopt the *persistence probability* α_k, that measures the 'cohesiveness' of the sub-graph C_k. A sub-network which has $\alpha_k > 0.5$ can be reasonably defined as a *community*. Obviously, the larger α_k, the larger the internal cohesiveness of C_k. Notice that, since α_k tends to grow with the size N_k of C_k it is necessary to test the non triviality of the community [4]. This can be done introducing the significance of α_k, identified by the standard z-score.

$$z_k = \frac{\alpha_k - \mu(\bar{\alpha}_k)}{\sigma(\bar{\alpha}_k)}. \tag{1}$$

where $\bar{\alpha}_k$ is the persistence probability of sub-graphs of size N_k, so that a large value of z_k (i.e., $z_k > 3$) denotes that the community is not trivially formed on the basis of the size of the sub-graph.

4 Results

Table 1. Number and characteristics of students and number of questionnaires and tests answered by students

Total	Males	Females	LS	HU	TE	Other	Q	T1 day 1	T2 day 4	T3 day 6	T4 day 8
589	402	150	415	57	55	42	369	535	505	500	331

Table 1 shows the number of students, their characteristics and the number of questionnaires and tests answered. We can see that the number of males is greater than the one of females, and that the students coming from LS high school type represent the majority. This confirms a general trend in STEM studies. In the next subsection, we focus on the cognitive variables to see how the students performed in the tests and how gender, school type and MOOC attendance impact test performance.

Test Performances. The students' performances in the four mathematical tests is shown in Fig. 2. Each test consisted of 10 multiple choice questions. Figure 2 shows the histograms of the number of correct answers out of 10 in each test. Even though it is clear that some tests are harder for the students than others, the distributions in the four histograms is similar. In general we have an asymmetric distribution with a heavy left tail and centred in the medium-high range of the scores. Further, it is also clear that the distributions of the scores can not be assumed as Gaussian: first of all, there is only a discrete set of 11 possible score values, and secondly the distributions are asymmetric. We then employ nonparametric statistical tools, e.g., methods that do not assume the normality of data.

We remark that, since all tests were done in different days, and collected anonymously, it is not possible to link the scores within students and the distributions of the scores gained in the four tests are considered separately. In order to understand how gender, school type and MOOC attendance influence the test scores, we performed a Kruskal-Wallis rank test [15] whose results show that the

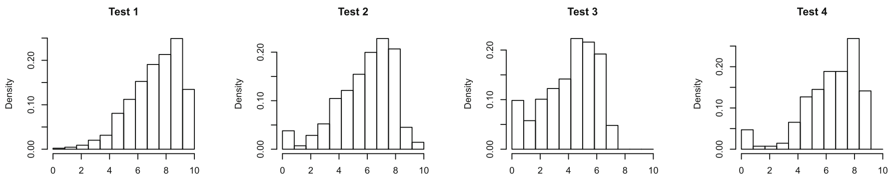

Fig. 2. Histograms of the scores in the four tests. T1 - Algebra, T2 - Geometry and logics, T3 - Calculus, T4 - Probability and statistics

test score is significantly related to the school in the first three tests, it is not related to the gender apart from test 2, and it is not related to the MOOC level.

To that end, we fit four regression trees to estimate the score of each test. We consider the test score as the target variable, which ranges between 0 and 10. We apply the regression tree method to single out which test score "characterizes" different groups of students. We have at our disposal 3 input variables: gender, school type and MOOC attendance. The construction of the tree is controlled by the parameter, our choice $\gamma = 0.5\%$, that is used to decide the minimum information gain to be considered for a split. For the four tests the results are similar, in terms of the order of the splits that are performed. Here we present and comment the tree obtained for the fourth test, that is the one characterized by a less significant relation between the covariates (school type, gender, and MOOC attendance) and the final score, at least when considering one covariate at a time. Our aim is to show that, also in this (say, worse) situation, a regression tree is able to identify a relation between the covariates and the test score and to classify the students into groups with different characteristics. Furthermore, in the context of our research, the students who answered to test 4 were the ones who were present in the last day of the Bridge Course: in this way, we are somehow (and indirectly) able to consider the students who actually attended a significant portion of the Bridge Course. The regression tree for test 4 is reported in Fig. 3.

We read the tree from the top to the bottom and at the top we read that the average test score is 6.7. We can see that the first split is determined by the school type: students from LS perform better (average test score 6.8) than the ones coming from other school types (representing 28% of the sample). In the latter case, no further distinction is made and the average test score for these students is 6.3. Among the students who come from LS, a second split is given by MOOC attendance: those with high attendance (score greater than 3.5 on a scale from 1 to 5) perform better than those who attended the MOOC less (i.e., <3.5). However, those who almost never attended the MOOC (i.e., <1.5) perform better than the students who partly attended it. Who are these students? Two groups of students are identified, at this stage: one group is made by those students who come from LS and dedicated time to watch the videos in the MOOC and to make exercises (these are the ones with the highest test average, namely 7.4); the other group is made of the students who come from LS, a school type where

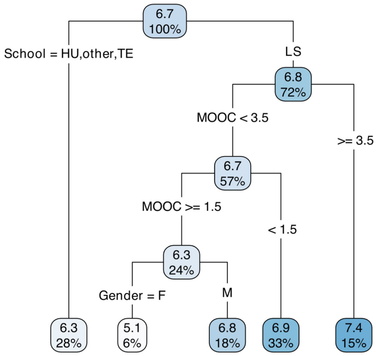

Fig. 3. Regression tree for test 4

math curriculum is strong, and hence they do not feel the need to learn more math on the MOOC. In fact, their performance is good (their average test scores is 6.7, which is higher than 6.3, namely the average of those who come from HU or TE school types). Among those students from LS who partly attended the MOOC, males perform much better than females. From this analysis, we have seen that the school types is the most influencing variable in test scores, but within the same school type we can identify different sub-groups of students who have different attendance at the MOOC. These differences may be better understood by looking specifically at affective variables (beliefs, attitudes, ...). This is the aim of the next subsection.

Community Analysis on Q. The community analysis on network N ($n = 369$ nodes) allows us to identify a partition with three clusters (modularity $Q = 0.0650$), whose details are reported in Table 2. The persistence probabilities (α_k) coupled with the z-score inform that the three identified sub networks of the whole students' network are not trivial.

Table 2. Results of max-modularity community analysis for students' network N

Community	N	N [%]	α_k	z_k
C_1	79	21.409	0.250	8.647
C_2	144	39.024	0.482	17.989
C_3	146	39.566	0.455	12.413

Figure 4 shows the communities' frequency of answers to Q0 in test Q: we can notice that community 3 has more males in percentage, more LS students (and fewer students from other school type), and more students who did not attend the MOOC course. Similarly, community 1 has a relatively higher percentage of male and LS students, while community 2 has a relatively lower percentage of

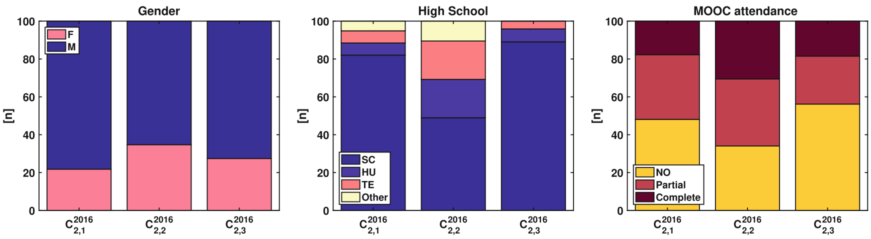

Fig. 4. Percentage of answers to personal data section Q0 grouped by community.

LS ones and the MOOC attendance is almost uniformly distributed among the three level of attendance. A χ^2-tests on the differences between the frequencies of answer to Q according to the identified communities shows that the three personal-level characteristics are statistically different in the three communities. At the same time, it highlights that the students in the three communities have answered in significantly different ways at all the questions but QA.3 and QA.4. The answers mostly given by the students belonging to the different communities to questionnaire QA allow us to characterise the three communities as follows.

Profile P_1: The students of this profile have a strong mathematical curriculum since they did not experience new math during the Bridge Course (QA.1). Since they declare to "have been exposed to problems different from the ones they were used to" (QA.2), they are unfamiliar with problem-based learning and they have a rather procedural approach to mathematics. Their exposition to procedural mathematics and more TO methods is confirmed also by the fact that they appreciated more the attendance part, instead of the e-learning part, the latter fostering more conceptual understanding (QA.5, QA.6).

Profile P_2: The students' sample has a large part of females and the majority of them come from HU, TE and Other schools, moreover two third of them attended the Pre-Calculus MOOC. The students belonging to profile 2 have a weaker mathematical background with respect to the previous profile, indeed they encountered new topics already in the bridge course (QA.1). However these students show a more positive attitude toward the e-learning material and the MOOC (QA.5,QA.6), suggesting a more conceptual approach and a positive attitude toward SO methods (QA.2).

Profile P_3: This profile is characterised by students who declared that they did not see any new topics (QA.1) or problems posed in different ways (QA.2). The sample is almost composed by LS students who have not attended the Pre-Calculus MOOC. However half of them would like a future support to the math exam as the *some extra tutoring as the same style of this course* and even a *support on MOOC* (QA.6). We can infer that students belonging to profile 3 have a very strong conceptual mathematical background and a positive attitude toward SO methods.

In the next subsection we come back to the classification tree and try to connect cognitive and affective variables.

Connections Between Affective Questionnaires and Cognitive Tests How do affective variables influence test performances of the students? If we go back to the classification tree shown in Fig. 3, we can identify the three profiles that emerged from the community analysis. After the first split, it emerges a group of students who come from HU, TE and Other schools and who have a lower test performance (average 6.3). These students can be identified with profile P_2. To the right of the split, LS students are identified and the ones with the highest test performance (average test score 7.4) have also attended the MOOC almost entirely. This group of students, which corresponds to 15% of the sample, seem not to correspond to any of the profiles. Among the students who come from LS and attended the MOOC less, we see another split: the leaf of the tree with the students who attended almost no MOOC identifies profile P_3, whose average test score is pretty high (namely, 6.8). The other leaf of the tree identifies the students coming from profile P_1: males are the majority and perform better that females in the test (average test score is 6.3 versus 5.1).

Even in an anonymous setting, we were able to establish a connection between the questionnaire and the tests by looking at the features of the students that *most characterize* the communities (i.e., gender, school type and MOOC attendance), and by seeing if the same features influence the test scores. It was then possible to identify four overarching, general trends that at a gross grain give a representative picture of well-known phenomena related to dropout.

5 Conclusions

In this paper, we aim at contributing to understand the phenomenon of drop out among first year STEM university students. We, thus, recalled the main factors that can help decision-makers to activate resources in order to reduce drop out by identifying and then intervening on subgroups of students who need personalised intervention at the first year of STEM university studies.

Our findings reveal that three main communities can be identified. The first community is populated by students who had been exposed to a strong curriculum in high school, and who have a rather conceptual view of mathematics. They show good performance in mathematics and they declare that in the Bridge Course they encountered mathematical content that was familiar for them: in fact, their acquaintance with conceptual mathematics allows them to feel comfortable with the new context of university mathematics, and not to live it as a shock. Finally, they seem to be able to discern which online content is useful for them: indeed, they declared to have partly attended the MOOC and our interpretation is that, since these students are good in mathematics, they selected the contents they actually felt "useful" for them to recall-being able to not loosing their time. As pertains this community of students, who represent the strongest group, our suggestion (following upon Clark & Lovric [5]) for policy-makers at STEM university is to promote and reinforce their relationships with high schools, especially focusing on secondary school math teacher training, so that teachers will teach their students more conceptual math, in a student-oriented fashion, and their learners will enter the university "well equipped" to deal with the transition.

A second community is as well populated by students who had been exposed to a strong curriculum in mathematics, but with a procedural approach. These students perform less well than their mates in the first community, they did not attended the MOOC and they are able to appreciate only traditional ways of teaching. A majority of males is present in this group. We can further comment that their math performance in tests is good enough, and they declare not to be shocked by the Bridge Course, because their strong mathematical knowledge sustains them in the transition. However, these students seem not to be ready neither for a self-organised way of studying, nor for student-centred learning formats. We expect that these students will face difficulties in the first semester at university, as observed in [2], a study conducted in a similar context. Andrà, Magnano & Morselli's [2] findings reveal that these students have the highest probability of not taking the degree, with respect to the students with weakest mathematical curriculum in high school-namely, those belonging to the third community.

Students in the third community are aware that their mathematical knowledge is not enough to attend first year STEM university, and they start to work hard in order to bridge the gap: they attend the MOOC and they come to the Bridge Course. They appreciate the new format of learning. According to [2], these students have a probability of getting the degree on time that is comparable to the one of the students in the first community. This tells us that mathematical knowledge is important, but it is also important the student's awareness about her weaknesses. For this reason, we suggest policy-makers at university to make use of (or develop their own) questionnaires that help them detecting the students' attitudes towards mathematics, their beliefs about themselves as learners, and their resilience.

From our findings, it emerges a confirmation of well established findings in analogous contexts. However, there are two elements of novelty in this study: one is the taking into account the students' attitudes towards e-learning materials (MOOCs, in particular), the other one is the idea of clustering students with respect to both personal-level characteristics such as gender and school type, and their views of mathematics, as variables that can explain their mathematics performances.

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Framework for Technical Elements in Collaborative E-Learning Platforms

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Abstract. Collaboration in online learning has become a prevalent part of our lives in recent years. More people study and work from home, which creates the need for many online platforms in our days to partially or fully support group work. In this line, the technical features present in collaborative e-learning stay unexplored; these features can determine whether a platform can support collaborative e-learning. The current paper is a detailed description of the framework, which was presented at HELMeTO Conference 2022 "Are you a collaborative e-learning platform". Our presented work is divided into two parts: the first one is a framework, where we identify the main collaborative characteristics of e-learning platforms. We divide our framework into three categories: the learning element, the communication, and the collaboration. In order to fulfill, even partially, the online collaborative learning, a platform needs to have at least one characteristic of each category. The second part of our work is a comparison among the existing e-learning platforms given the developed framework.

Keywords: Framework · E-learning · Collaborative e-learning platforms · Computer-supported collaborative learning

Website of the paper: https://collabeplatforms.wordpress.com/.

1 Introduction

Collaborative learning happens when users work together towards a common goal. Also, collaborative learning and computer-supported collaborative learning are on the focus of computing education in research [42] and industry [10]. With the increasing demand for online solutions and the digitalization of education, it is no surprise that computer-supported collaborative learning solutions are becoming popular. Research has shown that collaboration and working in groups can enhance cooperation with others [24], working performance, self-satisfaction, and innovation [2]. Additionally, collaboration is beneficially for the

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social skills of people participating in a group [39], as it can help them develop feelings of support and trust for other group members [34] and expand their knowledge by learning information from each other [34]. Moreover, it is shown that collaborators can increase the confidence for themselves and their skills [7], and gain expertise in managing tasks [8].

Collaborative learning is gaining attention and is an essential aspect of e-learning platforms and higher education. Collaboration can take place in both physical and digital spaces [10] either synchronously or asynchronously. Digital collaboration could happen in a non-traditional collaborative platform, such as a game-based learning environment [42]. There are no real limitations about the nature of the collaborative work in online environments, as peers can collaborate for a project-based scenario or can social exchange questions and ideas during a MOOC session and learn collaboratively. At the same time, collaborative platforms faced an increased demand due to the Covid-19 pandemic [1]. Although we hypothesize that it happened as an immediate solution due to enforced lockdown restrictions, it seems that online learning and online Collaborative learning are here to stay.

E-learning with a group work component is increasingly significant in higher education and learning. However, critical questions related to how collaborative learning looks in e-learning platforms, and what the necessary features are in an e-learning platform to accommodate online collaborative learning, stay unresolved.

This paper serves as a report on the technical characteristics of the collaborative e-learning platforms. The paper is structured as follows: at first, we study the state-of-the-art and present related works (Sect. 2). Then, we present our research methodology of creating the suggested framework (Sect. 3). Further, we establish the framework for analyzing collaborative e-learning platforms (Sect. 4) based on the necessary collaborative activities and elements as they are pointed out in the literature, and we provide a comparison of well-established e-learning platforms in collaborative learning based on the proposed framework (Sect. 5). We conclude our paper by providing a brief discussion about the future of collaborative e-learning platforms (Sect. 6). A detailed analysis of the paper and the platforms can be found on the paper's website[1].

2 Related Work

Our related work is formulated around frameworks for collaborative e-learning. "A systematic review of cloud computing tools for collaborative learning" [5] presents a table comparison of different cloud tools and collaborative learning activities similar to ours. Our difference with their study is that our focus is on e-learning platforms. A review of collaborative activities in CSCL [43] adopts a previous model of classification of collaborative learning process dimensions and separates them into the participative, interactive, social, cognitive and teaching dimensions. We adopt similar dimensions to our framework, as can be seen in Sect. 4.

[1] https://collabeplatforms.wordpress.com/.

Robert F. Bales [6] introduced 12 Interaction Process Analysis Categories, where the key idea is that people in small teams: show solidarity; shows tension release, jokes; agrees; gives suggestions; gives opinions; gives orientation; asks for orientation; asks opinion; asks for the suggestion; disagrees; shows tension and shows antagonism. Posea et al. [44] present a questionnaire-based framework for "collaborative project-oriented e-learning platforms", which can be used during the evaluation process for other platforms. Another framework, such as Active Collaborative e-Learning Framework (ACeLF) [35], "which is the foundation to develop e-Learning systems", consists of content knowledge, learning content knowledge, learning activity module, and recommending and monitoring module. DL Dowdle [17] proposes the framework of ten discrete activities, which "breaks down the whole process of analyzing, designing, developing, implementing and evaluating e-Learning". SC Kong [14] introduces "an e-Learning framework in school education", where he breaks down e-learning into technology and pedagogy. Badrul H. Khan suggested eight dimensions of e-Learning framework [33]: institutional, management, technological, pedagogical, ethical, interface design, resource support and evaluation. Oana Dodun et al. [15] mention different evaluation criteria, like cost, ease of use, security, performances, use the communication tools, content, motivational components, etc. Staff of brandon-hall.com [23] proposed "Six Steps to Implementing E-Learning", which are aimed more at the business sector, namely: Prepare for E-Learning, Develop a Strategy, Select Technology and Content, Sell E-Learning to Everyone in Your Organization, Implement Enterprise-Wide and Measure the Business Benefit.

All the listed articles served for us as foundational frameworks, which led us to the idea of creating the presented framework in this article.

3 Methodology

The need for the framework was generated by observing the lack of technical descriptions of the necessary elements to support online collaboration and learning. While developing a collaborative e-learning platform for schools and students, a developer needs to consider different questions, such as i) which features could be integrated into the e-learning platform?, ii) Which features are known to be present in collaborative e-learning platforms, and which are new?, iii) In which ways can people collaborate with each other?

The answer to these questions is presented in our framework which is the outcome of our research on the existing platforms and analysis on how people can work with together, exchange experiences, and learn new things. In general, all these attributes fall under the set definition of "collaboration". However, there is no common agreement among the existing online platforms, and each has unique features that support collaboration differently.

In order to create the framework of collaborative e-learning platforms, we followed the next steps:

Observation Inspired by Hearst [25], we were interested in collaborative e-learning platforms and wanted to realize the next-generation features these platforms should have. We checked for technical reports, reviews or studies for technical features in e-learning that demonstrate the state-of-the-art in supporting collaboration. After finding no satisfactory answer, we realized there was a gap in research we wanted to investigate further.

Current state To start the analysis, we needed to examine the current state-of-the-art features already existing in collaborative e-learning platforms. Therefore, our first step was to search for e-learning platforms that propose collaboration as one of the main elements. We realized early on that there was no common ground in specific suggested features and each e-learning platform offers collaboration capabilities in different formats. Therefore, we started gathering the different features found in these platforms.

Literature In order to gather these features in clusters, we advised e-learning frameworks from literature as described in Sect. 2. We found some interesting works that helped us group the features and formulated the basis for our framework.

Result The final result generated a detailed framework description which can be found in the next Section.

4 Framework for Analysing Collaborative E-Learning Platforms

Our framework is aimed at the subsequent analysis of existing collaborative e-learning platforms, which can help further analysis or develop new projects. By adopting [43] into an online setting, we identify three main characteristics that are necessary for collaborative online learning: 1. Learning element, 2. Communication, and 3. Collaboration.

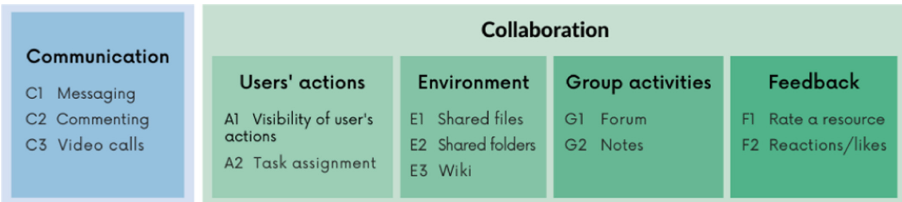

Fig. 1. Summary of our proposed framework and the specific platform characteristics.

4.1 Learning Element

As can be seen in Fig. 1, we exclude the learning element from our framework. We hypothesize that learning can occur in these platforms in different ways, such as by providing active learning processes in a medium that hosts lectures or learning content, for example, MOOCs, learning via question-answering, searching as learning activities and others. **An online platform can support -to some**

degree- collaborative learning if it provides at least one element in each of the Communication and Collaboration categories. Therefore, we further analyze the Communication and Collaborative elements categories into more detailed characteristics.

4.2 Communication

A crucial feature in collaborative platforms is communication. Communication among users is a key ability offered either in one-to-one basis or in a group setting. There are multiple communication features present in e-learning platforms, and we distinguish the following:

C1 – Messaging. Reading and writing messages enhances the participative side of the user [43]. Messaging can be partially presented; for example, on ALEKS [13] you can write messages only through the message center as an email (this also refers to *G1 - Forum*), and on edX, a user can write to another person through linked social network accounts.

C2 – Commenting. Commenting is another essential aspect of informal communication. It can take place on the personal user page or on the online content itself [47].

C3 – Video Calls. Online learning nowadays for formal education was pushed towards video calls. Researchers have found that video calls on MOOCs could enhance students' creativity [5].

4.3 Collaboration

Group work is an indispensable element of collaboration. Users can be grouped randomly or according to certain criteria, such as their interests, classes, and subjects. The group element refers to the ability of users to have a sense of team and reflects the social dimension of our framework. That could be achieved by various means. We present below our summary.

User's Actions. Users' actions reflect the participative dimension of the framework. By definition, the user can perform some actions on an online platform. Our aim is to identify the actions related to supporting collaboration from any user role perspective (students, teacher etc.). We distinguished the following characteristics for monitoring and displaying the recorded actions of the user or users' actions from the same group:

A1 – Visibility of User's Actions. Displaying users' actions to other users can improve the collaborative learning experience. Abderrahim El Mhouti et al. [19] show that the teachers' traces "allow the improvement of teachers to design-develop contents in a collaborative way." This feature can be partially presented in some platforms; for example, on edX [18] a user can see discussions and comments in the current course, and on Lecturio [37] you can see only the overview of your profile page

A2 – Task Assignment. From the teacher or moderator's perspective, the task assignment is an important factor for credibility and specific allocation of the workload of the team project. This feature is partially presented on ALEKS [13], where you can see assignments that a teacher assigned to you.

Shared Working Environment. Storing and sharing information with other group mates in the shared environment can significantly boost the working process because each user has their own experience and knowledge [45]. From our point of view, the shared working environment could be as:

E1 – Shared Files. Uploading files is one of the main collaborative activities [5].

E2 – Shared Folders. H. Zhang and M. Twidale [49] suggest shared folders for sharing the files with the colleges and for personal information management.

E3 – Wiki. Wikis provide flexibility and are important for instructors because they shift the focus "from the instructor-student interaction to peer relationships" [5].

Group Activities. The group communication element is essential to the social dimension. The ability to communicate "... is to facilitate easier communication for students and drive better student engagement beyond the traditional video tutorials from their online coaches."[2]. In the group activities between users within a group can be represented via:

G1 – Forum. For example, a forum can serve in a course setting where general questions can be asked and addressed and can be one of the productive collaboration elements [5]. For example, on JetPunk [32] a user can leave comments to the quiz/blog posts.

G2 – Notes. Note-taking could be one activity that increases teamwork productivity. Note-taking can be present in different formats, such as on Lecturio - to the current video, and on Microsoft Teams [38] as meeting notes.

Feedback. The ability to review the shared files, which users added to the shared environment, or to give feedback on the assignment is a parameter of collaboration. The feedback was found to be a major factor for the student's development of a critical attitude towards knowledge [5]. The feedback we find the features:

[2] https://www.cometchat.com/blog/top-chat-use-cases-for-e-learning-websites-and-apps.

F1 – Rate a Resource. Resources can be in different types and formats. One of the examples could be JetPunk, where users can rate the quiz.

F2 – Reactions/Likes. Reactions and likes have been shown from social networks to expand users' engagement. Likes can be in forum posts as well as in users' comments [47].

5 E-learning Platforms in Collaborative Learning

5.1 Platforms Selection

We present a selection of currently online platforms that have free or at least trial access, and we were able to test these platforms to try the existing features. Because of trial or free versions, some platforms have a limited list of available features, which can be unlocked only by buying a premium version. Also, we must note that platforms with premium access do not include in our report. We gathered the presented collaborative e-learning platforms and frameworks by searching with relevant keywords in Google Scholar and search engines. During the search were used the keywords such as "e-learning framework", "Collaborative platforms", "online collaborative framework" and "e-learning higher education". Besides, in our comparison table, we included only those platforms to which we did not have to ask for permission to register. For some of the platforms, a user should have a special code from their institute or an invitation, e.g. a special link to register on the platform from the organization. Some of the presented platforms do not fit the classical definition of a collaborative e-learning platform; however, they might provide features capable of supporting collaborative learning.

During the registration process on platforms (ALEKS, Canva, GitHub, Khan Academy and Moodle), where there was a choice of user type, we chose the "student" type. Some platforms support course recommendations based on the "highest level of education completed" (e.g. edX) or "What grade are you in?" (e.g. Khan Academy). In ALEKS, you can perform an initial knowledge check within the selected course to understand what knowledge you already have and what you need to learn. By Discord, a user can explore public servers (e.g., Gaming, Music, Education, Science & Tech, Entertainment, Student Hubs); by GitHub, there is an ability to choose "What specific features are you interested in using?" (e.g., Collaborative coding). On Lecturio, a user can register on the platform by choosing a category between Nursing, Medical or Institution. A detailed presentation of each platform in our comparison is available on the paper website[3].

[3] You can find the website describing this paper at https://collabeplatforms.wordpress.com/platforms/.

5.2 A Comparison of Collaborative E-Learning Platforms

We selected different platforms, which we analyzed based on our proposed framework. Table 1 shows a comparison of different platforms in collaborative e-learning, e-learning and non-classical e-learning setting. BBy analyzing the platforms based on our framework, we found that some have partially presented features. We also found that the most popular feature among communication is *C2 – Commenting*, and among collaborative elements are *G1 – Forum*, *A1 – Visibility of user's actions* (even partially), and *E1 – Shared files*. On the other hand, the least common features in a collaborative environment are the feedback either in terms of *F1 – Rating a resource*, and *F2 – Reactions/likes*. If we could categorize these features, we would argue that they exist in an older generation of features offered to users. Hopefully, in the future, we can see more e-learning and collaborative e-learning platforms supporting new technical features to better support students' and teachers' needs.

An interesting observation is that *many times e-learning platforms do not focus on the communication between the users*, often leading them to an out-of-platform link to social media platforms to communicate with others. This might not be a good practice, as interaction between users is vital for online collaboration. There might be a shift towards more enhanced communication capabilities in these platforms in the next years. Another captivating point is that non-classical e-learning platforms could serve as collaborative e-learning platforms, even to some degree. This realisation can increase online collaborative learning and spread it to the usage of previously undiscovered platforms. We believe our paper helps in this direction.

Besides the presented platforms, which fit the criteria to be a collaborative e-learning platform, there are *collaborative tools that can enhance a platform to host collaborative features*. Some of the tools are: BrowsingHistoryView [46], Coagmento Collaboratory [11], Elgg [20] and SearX [4]. All these tools are presented on the paper website[4].

Table 1 shows us only some examples of the collaborative e-learning platforms and what the comparison table might look like. The list itself, as well as tools, will be extended in the future and published on our paper website.

The limitation of the framework usage could be the lack of (technical) experience of the person, who will try to use the framework. Also, sometimes it can be hard to recognize whether the analysed platform has collaboration features, which we have presented in the paper, because these features could not be great visible to the end user. This could mean, that the collaborative features are only partially presented.

[4] https://collabeplatforms.wordpress.com/category/tools/.

Table 1. A comparison of collaborative e-learning platforms, where a tick in a circle (faIcon[regular]check-circle) - is a fully presented feature on a platform, a plain circle (faIcon[regular]circle) - partially presented (here partially means that the function does not directly correspond to our understanding of a feature implementation), faIcon[solid]user is one to one communication and faIcon[regular]users is a group (one to many) communication

	Communication			Collaboration							
				User's actions		Environment			Community		Feedback	
	C1	C2	C3	A1	A2	E1	E2	E3	G1	G2	F1	F2
Collaborative e-learning platforms												
Google Classroom [22]	✓	✓		✓	✓	✓	○					✓
Learnweb [36]		✓		✓		✓	✓		✓		✓	
Microsoft Teams [38]	✓		✓	✓		✓	✓	✓		○		
Moodle [16]	👥	✓		✓				✓	✓	✓		
E-learning platforms												
ALEKS [13]	👤				○	✓			○			
edX [18]		○		○					✓	○		
JetPunk [32]		✓		✓					○		○	
Khan Academy [3]		○		✓		○			✓	✓		
Lecturio [37]		○		○		✓			✓	○		
openHPI [40]		✓							✓			✓
Non-classical e-learning platforms												
Canva [9]		✓			○	✓	✓			○		
Coderwall [12]		○		✓			○		✓			
Discord [31]	✓	✓	✓		○	✓			○			○
GitHub [21]		✓	✓	✓	○	✓	✓	✓	✓			
Stack Overflow [41]	○	○		✓		○			✓			✓

6 Future Steps

We believe the next generation of collaborative e-learning platforms will have two directions in development: enhancing the platform's main features and adding new extra features. Both pillars can be based on recent advancements of AI to assist platforms in their efforts of improving users' involvement, feedback, group communication, and further generating personalised recommendations [26]. Enhanced collaborative e-learning platforms could benefit from the usage of Linked Open Data, such as educational ontologies [27], and Knowledge Graph technologies [28], e.g. an educational Knowledge Graphs [50], which can be used in combination with users' learning paths to achieve more personalised learning [29].

The first pillar, the enhancement of the main features, is based on the enrichment of the necessary characteristics of a collaborative e-learning platform, as described in our paper. Communication could get enhanced with more features provided for replies to group-mates, such as file sharing in a video call and multiple screen shares or even integrating virtual reality elements [48].

In the additional features, the platforms could add more visualizations to enhance project learning, such as a summary of the user's [26] and group's actions [30]. Also, the user could receive personalized recommendations based on their and their group-mates emotional state with emotion awareness systems implemented.

7 Conclusion

We present a technical report and guide to early-stage researchers in the collaborative e-learning field and a general rule-based specification for identifying a collaborative e-learning platform. We discussed the necessary characteristics of collaborative e-learning platforms, and based on these we presented a comparison of e-learning platforms.

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Digital Tools to Enhance Interdisciplinary Mathematics Teaching Practices in High School

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Abstract. Mathematics is a gateway to many scientific and technological fields. Almost every STEM advance and project is expressed in the language of mathematics. Educationally, mathematical development is central. Given the connections, it is reasonable to claim that curricula and pedagogical approaches should fully integrate all aspects of STEM and other domains. For this reason, it is important for teaching and learning to create interdisciplinary approaches that emphasize connections between the various domains while maintaining their own conceptual, procedural, and (epistemological) knowledge bases for each of these domains. To interconnect disciplinary knowledge, guaranteeing balance in curricular learning, it is desirable to promote integrated digital teaching practice. The paper is part of the debate about the possibilities of enhancing the role of mathematics in STEM education through interdisciplinary approaches.

The research questions refer to the type of digital tools and their use to support interdisciplinary approaches in the teaching and learning of technology-related disciplines such as mathematics and physics. This paper describes an interdisciplinary teaching practice format between mathematics and physics using digital tools as relevant mediators of meaning through the diverse representation that can be generated.

Keywords: Digital tools · High school · Mathematics · Physics

1 Introduction

STEM education plays a crucial part in preparing the workforce for the future global economy. As the economic development relies further on science and technology, there will be an increasing need for STEM professionals. Sarı et al. [24] suggest that problem-based STEM has significantly increased students' interest in STEM disciplines and careers. In addition, STEM education also equips students with the knowledge and skills needed not only in STEM-related jobs but also for working in other fields [1]. Mathematics is a gateway to many scientific and technological fields. In order to interconnect disciplinary knowledge, guaranteeing balance in curricular learning, it is desirable to promote integrated digital teaching practices. For example, Mathematics and Physics are disciplines that with their own specificities and without distorting them converge on

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common educational objectives as they favour interconnections of knowledge that normally lead to a deeper understanding. Failure to recognize this link within the classroom is the root of some learning difficulties, so much so that students consider mathematics and physics to be two very difficult, boring and disconnected subjects. Current teaching struggles to counter this trend, also because it continues to use registers and communication styles that are very distant from those of the students. The result of this contributes to the shattering of that world and reality that the developing mind intends to know, understand and interpret in its entirety [17]. A paradigm shift in teaching practice - which exploits the educational value of the subjects in the operational form of learning environments deriving from the real world - constitutes a good starting point for overcoming the focus on individual disciplinary contents in function of the development of learning for skills.

Integrated digital teaching (IDT), adapted to contextual conditions and characteristics even in pandemic times, favours a synergy between disciplines by virtue of the fact that it integrates physical and virtual reality. This allows students to build competencies through experiences based on conceptual themes in which mathematical and scientific thinking take place. Various aspects of the use of technologies to support the implementation of STEM education are considered by [8, 13, 15, 16, 21]. An important concept related to STEM education is interdisciplinarity. According to Morin [20], interdisciplinarity plays a pivotal role in the educational process. Teachers can improve their teaching practice by seeking connections both within a single discipline and between other disciplines on various levels of knowledge. In the educational process, interdisciplinary connections support a thorough comprehension of concepts and their meaning just because understanding is rooted in those associations and, thus, 'closed compartments' [5] can be avoided. For this purpose, the subjects of mathematics and physics seem to be the most appropriate, since these subjects have numerous epistemological parallels. While the modern application-oriented teaching of mathematics looks to didactic concepts of physics for experimentation, modern physics teaching also requires mathematical didactic knowledge to deal with technical problems via mathematics [2, 3]. Among the connections and integrations required for the creation of integrated teaching practices between Mathematics and Physics, it is important to highlight the role of the construction model as the representation of a given phenomenon as a true knowledge experience. The implementation of these practices allows the teacher to put the emphasis on higher register of language (functional, algebraic, geometric, cultural, technical-IT) in an active and tangible way, thus allowing the student to generate autonomous reflections suitable for an internalization of the contents and for construction of scientific thought. The aim of this paper is to advance the role of mathematics within integrated approaches to STEM education. Specifically, the research questions that guide the direction of this paper are as follows:

- What digital tools can support interdisciplinary approaches to mathematics in higher education?
- How can the use of digital tools enhance learning and teaching within technology-related subjects such as mathematics, and physics?

The paper is organized as follow: section two describes the theoretical framework, section three covers all the steps of teaching practice, and section four concludes and provides suggested recommendations for further research.

2 Theoretical Framework

Although the interdisciplinary approaches to STEM teaching are sometimes included in the curriculum the implementation in day-to-day teaching practice remains difficult, especially in the case of mathematics. The difficulty associated with integration appears to be related to three primary factors: first, the process of integration in itself is challenging; second, there is a lack of trust in the capacity in STEM teaching; and third, preparation in initial teacher education programmes is mostly concentrated on two areas of disciplinary expertise (and usually not mathematics), and this has the potential to narrow perspectives on the importance of other disciplines [18, 28]. Therefore, if an aim of STEM education is to support students in connecting key ideas across disciplines, it is vital that the origin of knowledge from different disciplines be made explicit. At the same time, some have sounded a warning that attempts to bring different disciplines together to bear on a real-world problem should remain meaningful so as not to inadvertently undermine student learning in those subjects [30].

Preparing students for the society of the future also means asking oneself what mathematics we should teach, -especially when digital technologies can do most of the mathematics we teach at the moment.

Resources such as digital tools, media, and simulations hold great potential to support the educational processes in mathematics. A substantial amount of research has proved that the use of digital tools may allow teachers to create suitable learning environments, with the goal of promoting the construction of meanings for mathematical objects [7, 9, 19, 31]. Several studies show that the use of digital tools can support skills and strategies that are highly relevant in the scientific and mathematical content area, such as real-world problems or visualizing complex relationships (e.g., [11, 14]). They can support learning through interactive and scaffolded activities (e.g., [4, 23]). In addition, manipulating representations in computer simulations can support model-based learning—as students may understand mathematics and science concepts more elaborately because they observe direct consequences of the changes they make [6]. In mathematics, for instance, dynamic tools such as GeoGebra enable students to learn abstract subjects, such as geometry, algebra, and calculus in an interactive and explorative manner [11, 12]. Moreover, the use of GeoGebra offers new perspectives on geometry in the school setting, in addition to more advanced levels by clearly facilitating the experimentation and exploration of geometrical formations and linkages [10, 25, 27]. STEM teaching and learning can be implemented in various forms at different levels of integration; a higher level of integration is harder to achieve since it requires more planning, collaboration, and time to execute [32]. Moreover, Srikoom et al. [29] revealed four dimensions for effective STEM teaching practice and their characteristics for long-term learning. At any level of integration, the reciprocal relationship between mathematics and other STEM disciplines must be addressed. This all requires pedagogical approaches such as engineering design thinking, inquiry-based teaching, projects, and problem-based learning to establish effective education delivery from multifaceted perspectives through STEM integration. An inadequate focus on assisting students (and teachers) to recognize and make mathematics connections to the remaining disciplines further contributes to undermining mathematics learning within STEM. Making the role of mathematics explicit by repeatedly foregrounding the desired content and temporarily backgrounding other STEM content is one way in which the discipline might be advanced.

3 The Interdisciplinary Teaching Practice with Digital Tools

Coming from the theoretical framework, the teaching practice focuses on the digital construction of the geometric model that describes the physical phenomenon related to mechanical wave interference. The goal is to make students aware of how Mathematics interacts with Physics by providing conceptual tools needed to solve a problem. The teaching practice, easily transferable to the classroom, exploits the scientific method mediated by technology according to three curves: ecological (adapted to operational constraints of time, space, and infrastructure), epistemological (develops/consolidates disciplinary knowledge associated with the evolution of concepts present in the student's background), existential (favours the understanding of the representations, values, and identity related to the two disciplines).

The digital tools used are different. Specifically, an interactive simulator is used first by means of an app, through which the students can "fiddle" with all the variables involved; then for mathematical modelling the GeoGebra software is employed to gain direct experience, at different levels, with mathematical concepts and/or contents. In this way, students have the opportunity to virtually simulate both the physical phenomenon and to be able to represent the geometric model in a constructive way by exploring properties, formulating conjectures, and testing them by exploiting the features offered by GeoGebra [26]. This translation process encourages and stimulates creativity and favours critical thinking. As result of this, the teaching practice is designed upon two pillars:

1. a didactical model for coordination and mutual interaction between mathematics and the physical phenomenon;
2. the conception of modelling as an interdisciplinary competency.

The physical phenomenon offer the students the opportunity to develop situation-specific methods and symbolizations. Then the methods and symbols are modelled from a mathematical perspective, and in this sense mathematical models emerge from the students' activity. The models first come into being as a model of the situation, and then the model gradually becomes an entity in its own right and begins to serve as a model for mathematical reasoning.

3.1 Observation and Description of the Physical Phenomenon

A classic example of a wave phenomenon is examined: the fall of a drop of water into a container containing water at room temperature.

The observation takes place through interactive simulations proposed on the home page (https://phet.colorado.edu/it/) of the site dedicated to the project PhET, of the University of Colorado. At the start of the simulation "Wave interference" the students are faced with the screen shown in Fig. 1.

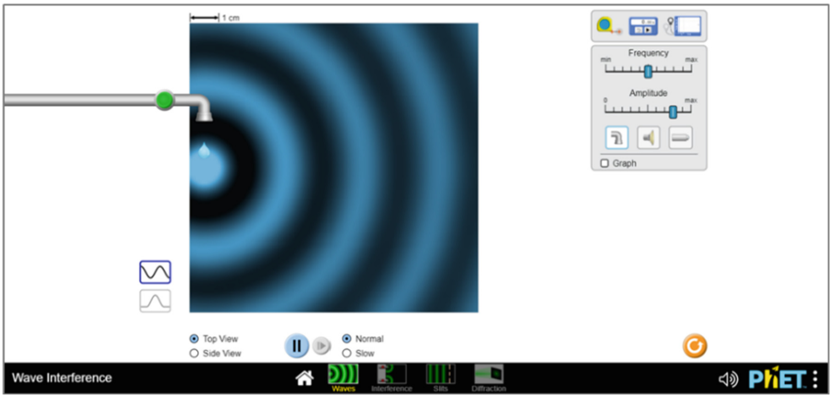

Fig. 1. Interactive simulation with a single tap and viewed from above.

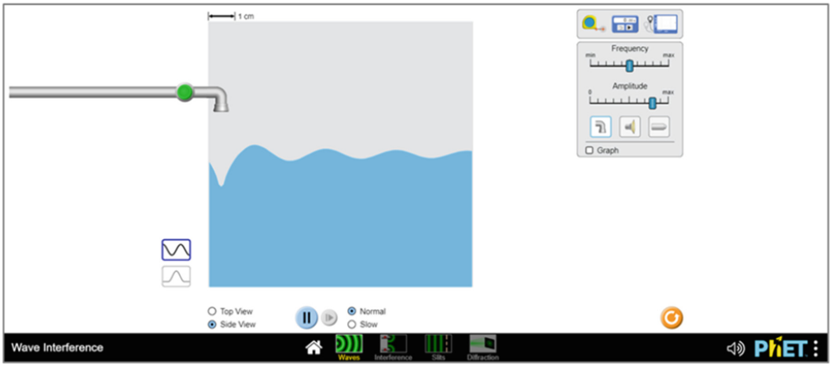

Fig. 2. Interactive simulation with a single tap and visualization from the side.

The interactive simulator can be started or stopped at any time; it is also possible to vary the physical variables involved (e.g., wave amplitude and frequency). It is also possible to choose the type of display - from above (Fig. 1) or sideways (Fig. 2). The students literally "fiddle" with the interactive simulator and at the end propose some interesting observations:

- as the frequency decreases, the amplitude of the time interval between the fall of one drop and the next increases;
- as the frequency increases, the amplitude of the time interval between the fall of one drop and the next decreases;

- as the amplitude decreases, the amount of water falling from the tap decreases;
- as the amplitude increases, the amount of water falling from the tap increases.

The students, stimulated by the teacher, are called to describe the physical phenomenon. The following emerges from the conversation protocol: "… the circular ripples that form on the surface widen more and more until they disappear", and again "… the movement of the water that is generated from the point where the drop of waterfalls propagates on the surface, drawing a ripple of a progressively increasing radius".

The observation of the physical phenomenon represents the stimulus to introduce the topic of mechanical waves. The teacher proposes other examples to the students focusing carefully on the properties of mechanical waves, highlighting the characteristics of the waves already "observed" and "manipulated" during the interactive simulation.

3.2 From the Physical Phenomenon to the Mathematical Model

The teacher suggests that students observe the phenomenon through a different lens, which is to say from a mathematical point of view. The students, for their part, often immediately answer in chorus: "From the point where the drops of water fall, concentric circles are generated!".

Students are asked to represent the mathematical model (construction of concentric circles) with the GeoGebra software. The geometric objects that are used are the following: the point, the circumference, and the slider, a fundamental tool for the "animated" reproduction of the phenomenon. The output is shown in Fig. 3.

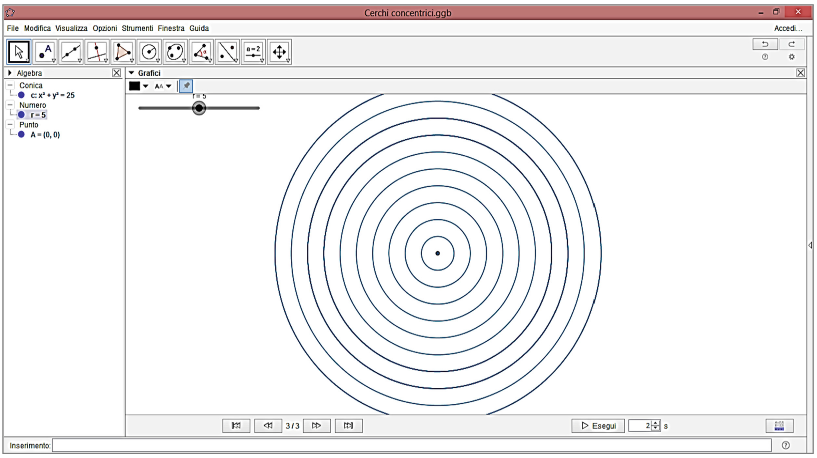

Fig. 3. Mathematical model output.

3.3 The Interference Phenomenon

The teacher asks the students to simulate the fall of a drop of water using the "Two taps" option (Fig. 4). The simulation leads is designed so the students face the relative physical phenomenon called 'Wave interference'.

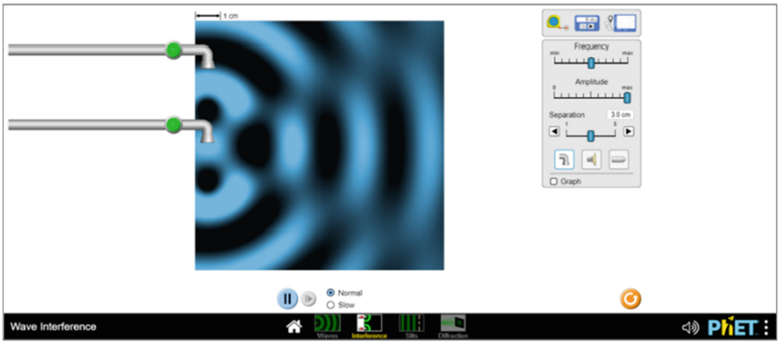

Fig. 4. Interactive simulation of wave interference.

From observing the phenomenon, the students notice "the circular ripples that form on the surface overlap each other". This acts as a stimulus to introduce the superposition of waves and specifically the interference of waves, a property that is observed when two sources produce waves of equal amplitude and frequency. In the case in question, the sources are similar to the two drops of water that fall from the two taps. This new simulation also leads to mathematical modelling with the GeoGebra software (Fig. 5). Students are asked to identify the properties of and among the geometric objects in play.

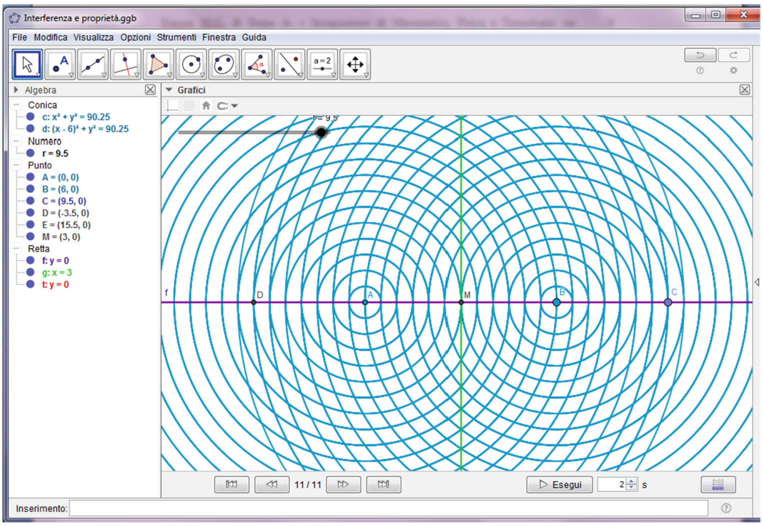

Fig. 5. Output of mathematical model of the interference of waves.

From the simulated mathematical model in Fig. 5, the students create a table (Table 1) summarizing the objects used together with their different meanings.

Table 1. Synoptic table of objects accompanied by different meanings.

Objects	Physical meaning	Mathematical meaning
A, B	Sources of two waves	Points in Euclidean plane
c	Waves generated by source A	Circle with centre A and radius $r > 0$, depending on the slides
d	Waves generated by source B	Circle with centre B and radius $r > 0$, depending on the slides
M		Midpoint between point A and B
g		Straight line passing through point M and perpendicular to the straight line passing through points A and B

The following observations complete what is explained in the table:

– The straight-line g is the symmetry axis of the geometric model.
– Fixed an instant t, the concentric circles − generated starting from the point/sources A and B − have the same radius because the frequency and amplitude have the same numerical value.

4 Conclusions

This example of teaching practice stresses the importance of modelling activities in an interdisciplinary context between Physics and Mathematics. The shift presented from ‘a model of’ to ‘a model for’ should concur with a shift in the way students perceive and think about the models; from models that derive their meaning from the context situation modelled to thinking about the mathematical content of the models.

In mathematics modelling competence includes structuring an intra –or extra-mathematical situation, analyzing and tackling the model, interpreting the results, validating the model, communicating about the model, and monitoring the modelling activity [22]. With multimedia capabilities, students can visualize mathematical concepts that are difficult to imagine using the traditional methods of teaching. Apart from saving time during the drawing work, these options help to identify invariant relations, and generalize problems and their solutions. GeoGebra offers a new approach to teaching because it helps to create mathematical objects and explore them visually and dynamically. Promoting new possibilities of using appropriate digital tools which are -freely available is central to STEM education. An important aim of this is that is better to prepare individuals to deal with complex real-world problems that require the application of knowledge and skills from different disciplines in a critical and creative way.

It is important to prepare students for the continuously increasing demand for quantitative and computational literacy in the twenty-first century. Students can acquire an understanding of concepts, methods and tools of the different scientific disciplines in a more meaningful way through a teaching aimed at favouring the connection of these with real life.

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Capability Approach and Sustainability, a Survey for the Faculty Development in Higher Education

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Abstract. Higher Education must cope with a complex intertwining of challenges that places university teachers in a condition of continuous updating. With this in mind, we intend to deepen the theme of Faculty Development (FD) with specific reference to the fascinating intertwining of the Capability Approach (CA) and the objectives of the 2030 agenda.

What connects the boost provided by studies on FD and the CA is the invitation for teachers to train active, responsible citizens capable of critical reasoning and problem-solving skills.

An investigation is being carried out for the in-depth study of the topics exposed at the University of Palermo. The research group envisaged the involvement of the students attending the Degree course in Pedagogical Sciences (289 students) - a.y. 2021/2022.

The research process activated sees both students and the research team as protagonists, as it allows to activate a reflective action on teaching practice to be able to constantly improve it and raise its quality. The survey aims at under- standing how much future pedagogues know the 17 objectives promoted by the 2030 Agenda. According to what has been said, it is therefore a preliminary reflection step that precedes an experimental intervention, expected for the next academic year, that will be based on the implementation of activities workshopsdesigned and implemented using the CA and which focus on the objectives of the 2030 Agenda. The tool used is the "Capability Approach and Sustainability" questionnaire created and built by the research group and the data analysis is quantitative.

Keywords: Capability Approach · Sustainability · 2030 Agenda · Faculty Development

1 Theoretical Framework

The horizon of meaning outlined by the capability approach defines a primary and preliminary social responsibility: outlining the characteristics of the context to define the possibilities of acting, imagining, promoting, predicting. Therefore, the CA expresses a competence to act, in all contexts of life, from school to professional, defining the objectives that every single person is preparing to achieve. It, therefore, becomes an

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essential right for the full flowering of the human being, for the expression of citizenship and democratic participation. Through the CA perspective, human capi-tal incorporates another aspect: the dimension of lifelong learning and learning by doing, stimulating learning in formal and non-formal contexts, and aiming at the acquisition of cognitive opportunities and the development of capabilities.

As a matter of fact, Nussbaum's capabilities approach is a constant reassessment of the answer to the question: what does the prosperity of a nation or region of the work and the quality of life of its inhabitants consist of? [1].

The CA also meets the issue of sustainability in the educational-teaching field, directing the focus of research on the teacher and on the teaching design that is implemented daily in professional practice.

The 2030 Agenda for Sustainable Development in this sense is a crucial document; it carries out an action program for people, the planet, and prosperity. The 2030 Agenda incorporates 17 Sustainable Development Goals, SDGs - into a large action program that reveals a total of 169 targets or milestones.

The sustainability philosophy encompasses three interrelated dimensions [2]: human development, social justice, care for the environment. The paradigm of sustainability and the perspective of the CA find a point of possible convergence for pedagogical reflection also around the theme of the community [3]. The purpose of global development, like that of any good national development policy, consists of promoting the growth of the capabilities of everyone [4].

In this perspective, it is the 2030 Agenda itself that identifies community cohesion as one of the key elements for building an enabling environment for the full realization of rights and the putting into practice of the abilities of children and young people [5].

The agency represents the effective opportunity of the subject to exercise his freedom in terms of skills, or ways of acting, doing and being that guarantee his full development as a human being, respect for dignity and the promotion of individual well-being and collective [3].

1.1 Capability Approach and Sustainability

The Capability Approach (CA) allows us to operate pursuant of an existential conception of holistic well-being, with a view to development intended as promotion and realization of individual and collective well-being [6–8].

The CA perspective, although it was born in economic field, lends itself to a pedagogical dimension, for an identity construction related to sustainable development and to person concrete becoming.

As U-Haq [9] claimed, the CA embodies the possibility of "Human Development" understood as development "for", "through" and "of" people. In this perspective, the possibility development to act, to participate, and to reach the state of empowerment is fundamental, as essential rights for the full growth of the human being, for the expression of citizenship and democratic participation.

According to Sen [8], an agent is who determines changing; it follows that agency coincides with what is acquired in terms of values and objectives connected with one's own and others' well-being. For this reason, the concept of agency translates into a value with a double value: personal and community [10].

Agency is determined by both personal and social assets and abilities and both human and material resources [11].

Martha Nussbaum [12] resumes the concept of capability proposed by Sen, articulating the construct in three dimensions: innate skills, internal skills, and combined skills. Furthermore, these have been declined by scholar into ten skills that reflect the minimum threshold that a government has to strive to achieve for all citizens. “Since the task of the government is known and widely shared (that is, to make people able to live a dignified and sufficiently flourishing existence), it results that a good political order has to guarantee all citizens at least the following threshold of ten central capac-ities» [12]: life, physical health, physical integrity, senses, feelings, practical reason, belonging, other species, play, control of one’s environment.

This multi-perspective view of skills was taken from UN as part of the Human Development Report of 2010 for which they are considered fundamental for global economic growth.

The approach crux is that each human being could fully live according to their own abilities, carrying out, on contrary to human capital policies, an unprecedented moral imperative [12]. Only in this way we can speak not only of welfare but rather of wellbeing, which is the well-being condition in social life multidimensionality [13].

As Alessandrini highlighted [2], “the theme of human development - in particular the approach to skills (Nussbaum/Sen) - is a fundamental point of reference to rethink educational practices from a generative reference to new educational values Centred on inequalities contrast.

Therefore, it is necessary to question how pedagogical research can “intercept” these challenges to propose a culture of sustainability [5] starting from schools, forming the new generations, by learning processes of an eminently transformative and generative nature [14, 15].

1.2 Capability Approach and Agenda 2030

The Agenda 2030 for Sustainable Development is an action program for people, planet and prosperity action, signed in September 2015 by the governments of the 193 UN member countries. It incorporates 17 Sustainable Development Goals - SDGs - in a large action program for a total of 169 ‘targets’ [5].

The official Sustainable Development Goals launch coincided with the beginning of 2016, providing a time frame of 15 years. The Development Goals respond to previous Millennium Development Goals outcomes, and represent common goals on aset of important development issues: the fight against poverty, the eradication of hunger and the fight against climate change, to name but a few, etc.

“Common goals” means that they concern all countries and all individuals: no one is excluded, and no one should be left behind on the path towards sustainability.

Capability education is seen as a space of freedom and citizenship education and as an education in individual and collective responsibility.

Alessandrini [2] has long reflected on the relationship between CA and sustainability, developing a clear overview of common elements. Among them:

– the awareness that economic development is not identified with human developent;

- the vision of contrasting the diffusion of a market-based and functionalist aproach to development;
- the primacy of attention to "common good";
- the refusal of an individualistic and private vision of knowledge;
- primary attention to the need to safeguard the dignity of everyone.

The agency represents the subject effective opportunity to exercise his freedom in terms of skills, i.e., ways of acting, doing and being that guarantee his full development as a human being, respect for dignity and promotion of individual and collective well-being [16].

This would allow us to imagine an educating community in which all the resources found within it, from human to economic and social ones, act in a synergistic and cooperative way to create capacitive contexts [17].

In this perspective, the 2030 Agenda identifies community cohesion as one of the key elements for building an enabling environment for rights full realization and to putting into practice the abilities of children and young people [5]; not for nothing the reference to the term community is quite frequent in the declination of the 17 objectives and 169 targets for the implementation of sustainable development.

Pedagogy for sustainable development, therefore, cannot stop at initiatives limited to schools, but is called upon to contribute to promoting awareness of the interdependence between the natural environment and human action in a lifelong perspective, and life-deep learning declined in reality of processes, behaviours and actions that manage to express and realize the capabilities of each one to the fullest extent possible, in an essential ethical dimension based on equity, inclusion, well-being intended as quality of life and surrounding environment, planetary and interplanetary [18].

To respond to the educational challenges nowadays posed to education world, it should be paid attention to people and their potential, working on engagement, responsibility, leadership and inclusion of all internal and external actors in educational contexts. [19–22].

The complexity given of the phenomena object of interest, needs to work at several levels on the promotion of sustainable education [2]. As Giuliani and Moretti claimed [22], in fact, it is not enough to look only at students, but it is also necessary to work on teachers, schools, universities and training bodies, up to the policy makers.

1.3 Faculty Development

The expression "Faculty Development" (FD) does not have a unique definition. There is no doubt that this construct has developed in the English-speaking world (the United States and Canada at the beginning) since 1970s. Over time, however, someone understood it in its widest sense as a range of activities designed to support faculty performance in all aspects of professional life such as teachers, scholars, consultants, academic and institutional leaders, citizens [23]. Other scholars, furthermore, have focused on the development and renewal of teaching, meaning by expression FD a series of activities aimed to students' learning improvement and to help teachers improve their skills as learners [24]. More recently, we talk about FD to indicate the opportunity for professional development for individual teachers, departments, colleges, and institutions [25].

Due to this different evolution by the time, we can say that the expression FD could indicate various actions aimed at [26]:

- promotion of reflective practices related to different roles of the university teacher;
- promotion of specific teaching skills of university teachers;
- promotion of curricula reorganization according to the skills paradigm;
- promoting the creation of communities of practice relating to university learning and teaching;
- promotion of forms of exchange and dialogue than that these issues through the creation of communities of an interinstitutional nature (also at the international level). According to Steinert [27, 28], moreover, it is possible to arrange the actions of the FD on two axes: on the first one it is possible to arrange those actions that involve individual or group learning forms; in the second one it is possible to discuss formal or informal learning actions. The intersection of these two axes emerges a classification which provides for formal activities based on individual learning (such as: online learning, peer training, feedback from students); o formal activities based on group learning (such as: workshops and seminars, fellowships, longitudinal training programs). In addition, informal activities based on individual learning (reflective activities, learning from observation, learning by doing); o informal activities based on group learning (work-based learning, community of practice).

  "Whatever delivery modalities are of the Faculty Development programs and modalities through which the change is produced, it is possible to observe how these actions lead to a positive change relative not only to the actions but at a deeper level.
- to the attitudes and beliefs that guide the choices of teachers with regard to the educational principles they bear" [26].

2 Research Section

The research activity involved the design of an investigation tool that would be aimed to understand how much future pedagogues know the 17 objectives promoted by the 2030 Agenda.

Specifically, the construction of the tool consists in a survey formulation and take place from a long reflection on the topics exposed, on the ISTAT data relating to goals 4 and 13 of the 2030 Agenda [5].

The questionnaire inquires future pedagogues who are beginners about the achievement of the goals and the consequent e connection with the size of the CA.

The research action is divided in two part: the first one is oriented to training the students of the Degree Course in Pedagogical Sciences attending the following subjects: Methodology of Research in the Education(189 students) and Docimology laboratory (200 students) - a.y. 2021/2022; then, the second part is an Experimental intervention, expected for the next academic year, that will be based on the implementation of activities workshops designed and implemented using the CA and focusing us on the objectives of the 2030 Agenda.

2.1 The Recipients

The students of the Degree Course in Pedagogical Sciences attending the Methodology of Research in the Education (189 students) and Docimology laboratory (200 students) during the a.v. 2021/2022 were the recipients of the research action. The sample was analysed to understand the mean categories of which it is made up.

Based on the age (see Fig. 1), the sample is mostly composed by people who are between 21–25 years old, while the 20% of the sample is almost equally divided between 26 and 46 years old.

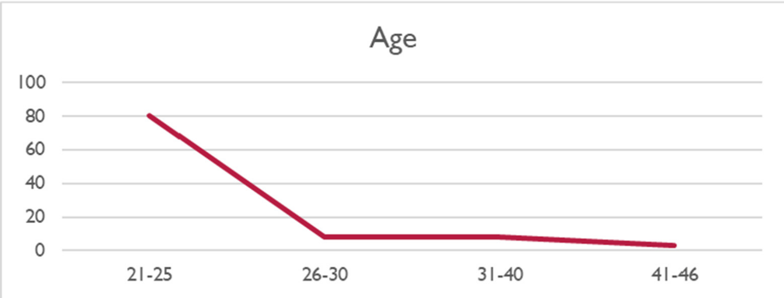

Fig. 1. Age of participants

The sample have been selected form university classroom, so it is mostly composed by students, nevertheless the 20% of the sample is employed (see Fig. 2).

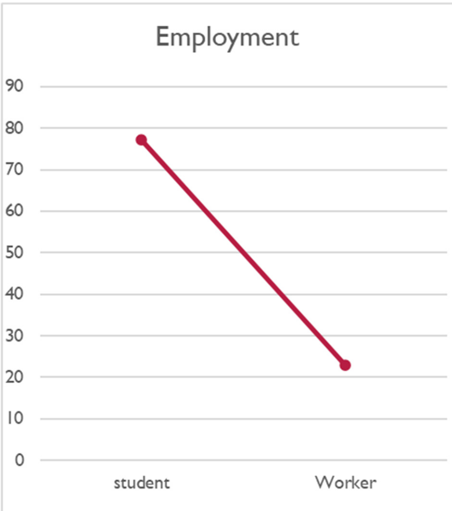

Fig. 2. Employment situation of participants

The sample is quite heterogeneous on the level of education point of view. Almost half of the sample are students attending the early childhood education course, 40% is equally divided in students attending socio-pedagogical education and community education. The last 10% are students that already get another bachelor or master's degree (Fig. 3).

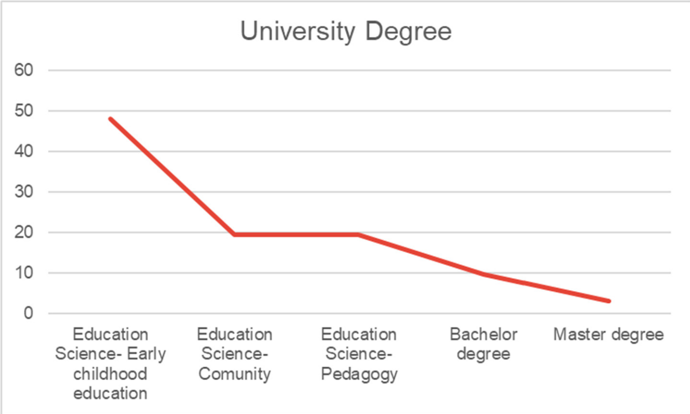

Fig. 3. Qualification of the participants

2.2 The Tool

The tool prepared for experimental action is a questionnaire created by Google Forms platform, it is made of three sections.

The first section consists of a personal data part, which requires generic personal information, while the second section is based on knowledge of the following data:

- 2030 Agenda drawn up by the UN;
- Global Goals Kids Show created by the Italian Alliance for Sustainable Development (ASVIS: Alleanza Italiana per lo Sviluppo Sostenibile);
- National Indications and New Scenarios drawn up by the Ministry of Education;
- Report "Education in a post-COVID world: nine ideas for public action" prepared by the International Commission on the Futures of Education established by UNESCO.

The third section of the tool is centered on goal 4 of the 2030 Agenda, "Providing quality, equitable and inclusive education, and learning opportunities for all".

The section consists of fifteen items, the indicator is a frequency scale from one to five. Each item asks the student about his or her work within the class aimed to achieve the aforementioned goal.

2.3 Data Analysis

As the graph shows, the total answers obtained was 1081 (higher than sample people, 389), since each student had the opportunity to insert one or more objectives of the

Agenda, for this reason calculations were scaled on the total obtained (See Fig. 4). The best-known objectives by the reference sample are No. 4 (Quality Education), No 5 (Gen-der Equality) and No 10 (Reducing Inequalities), which are above 10%. Then goal 3 (Health and well-being), no. 13 (Combating climate change), no. 15 (Life on Earth) and no. 6 (Clean water and sanitation) have been selected, although for fewer students, as they are less present in their answers.

Finally, there are some of the objectives rarely selected by the sample, due to their not malleability to integration into everyday teaching. They are no. 17 (Partnership of objectives), no. 8 (Decent work and economic growth), no. 1 (Eradicating poverty) and no. 9 (Enterprise, innovation, and infrastructure).

The most contrasting data are related to only 1.76% of students who don't know the 17 objectives of the 2030 Agenda (Point 18). This leads to a reflection on the goals used in current educational paths.

It would be desirable to invite teachers to raise awareness in students on a wide range of issues, integrating them in interdisciplinary paths or in civic education ones, providing a range of choices on which to direct the ethical and moral growth of each.

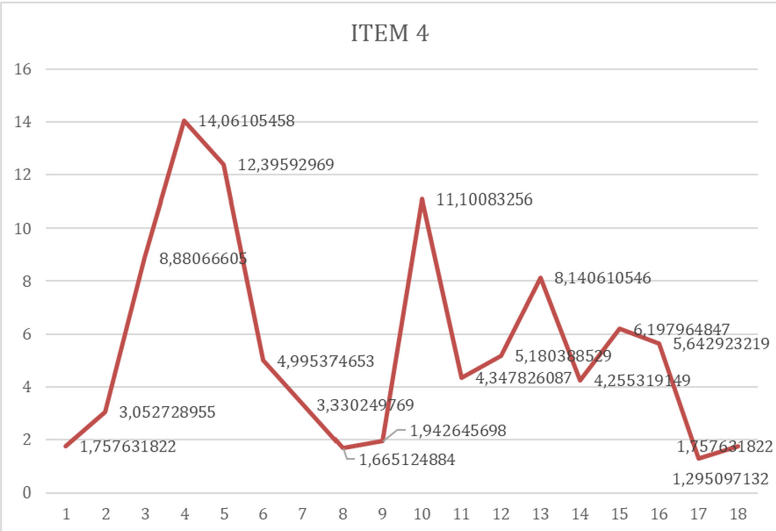

Fig. 4. Item 4: students' knowledge of the agenda 2030

In the third section of the inquire, which is related to the field of quality education, it is consequential to conduct reflection on a fair and inclusive education, which allows every pupil, even those who are in a situation of socio-economic and cultural disadvantage, to aspire to the maximum (See Fig. 5).

This dimension includes access to teaching materials, which, to guarantee the right to study, must be accessible to all, while respecting equal skills and opportunities.

This item helps to draw a positive and encouraging picture, as it defines how, in the absence of materials, schools will succeed to provide them to pupils; despite 35.94% of respondents placed the response values between 1 and 3, It shows that there are schools in which materials are completely missing or are provided occasionally.

As results schools, especially in difficult contexts and/or neighbourhoods, probably need more help and support from the state, by supplies for pupils, to increase the degree of involvement of students.

Fig. 5. Item 8 of the Objective 4 section: "The school supports the individual pupils' educational path by providing the school material if, for various reasons, it is not available, so as to provide the fairest and most inclusive education".

The last item of the section has been written through the creation of inferences between the CA and the paradigm of sustainability, significant in the above mentined section of the instrument. Item 15: "Teachers aware of being an autonomous community of elaboration of reality, will give their pupils the opportunity to develop, through their imagination, ever new interpretations of the world and to offer solutions for positive change" (see Fig. 6).

The data show that most of the teachers of the interviewed students offer an experience close to the realization of their potential, making them develop innovative skills, which will be substantial for changing of the future.

The analysis of these factors defines a dimension towards which the school is heading, i.e. a new way of dealing with current problems, especially with regard to the awareness of pupils on mutual respect and on respect of environment in which they live.

The nowadays teacher, destined to become the one of tomorrow, is aware of its pupils' abilities and knows how to push on strengths and especially on weakness, devising innovative solutions in view of their future, for a greater involvement of the personal sphere of each one.

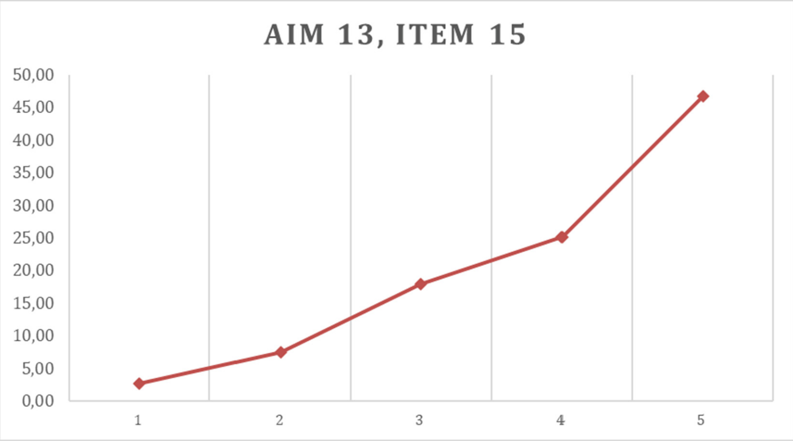

Fig. 6. Item 15 of the Objective 13 section: "Teachers aware of being an autonomous community of elaboration of the real, will give the opportunity to their students to develop, through imagination, new interpretations of the world and to offer solutions for positive change".

3 Conclusion

The intention to relate the two paradigms aims to an integral development of the student. In this way it is possible to enhance personal specificities to become a social capital.

Looking at the future, it is essential to educate the new generations to respect the planet and others, stimulating the creation of a society based on individual well-being that systematically becomes collective.

School has all the potential to bring the professionals of tomorrow to be professionals of life. The change must start from the bottom and by the work of each teacher, it can reach the highest grades, to lead to a total change of the school, creating a real educating community without distances or differences.

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Quality and Accessibility in Blended Learning and Hybrid Solutions at Higher Education Level: A Word from the Students

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Abstract. The educational quality of hybrid solutions relies upon their capabilities to foster meaningful learning and support collaborative and learner-centred instruction. Higher education faculty's and institutions' preparedness for delivering hybrid/blended instruction is crucial and it has not always passed the test for quality education in the past few years, especially when the Covid-19 pandemic forced the online transition. This study focuses on the educational quality and accessibility provided by hybrid/blended learning solutions (HBLS) at the university level, as perceived by the primary protagonists of education: the students. Six hundred and eighty higher education students completed an online survey on perceived quality and accessibility provided by the hybrid and blended learning solutions activated at their university. A cluster analysis on the participants revealed three patterns of response in terms of quality and accessibility appreciation: a dismissive, an appreciative and an enthusiastic profile. Implications for higher education response to the specific student characteristics are discussed.

Keywords: Distance learning · Higher education · Hybrid education · Student voice

1 Introduction

Technology integration can radically change how we teach; how we manage instruction, where and when it occurs; how we relate to knowledge; how we relate to a group; how we interact with students, colleagues and the community [1]. One way to systemically integrate technology in education and realize those changes is through hybrid and blended instruction. There are several ways in which hybrid and blended learning solutions (HBLS) may support learning, ranging from the addition of online activities to a traditional in-person course; to the use of blended learning pathways through specific platforms as integrated learning environments; to the systematic flexibility in instructional spatial/temporal distribution between presence and distance [2]. According to Kalantzis and Cope [3], adopting online teaching - boosted by the recent pandemic -

Authorship: 1. Introduction, 5. Discussion and conclusions (Marina De Rossi); 2. Literature background, 3. The present study; 4. Findings (Ottavia Trevisan).

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calls into question the conventional wisdom that face-to-face learning is the gold standard (p. 51).

Indeed, there has been a significant shift to online teaching and learning in higher education as a result of the global Covid-19 pandemic, which some authors have referred to as the Great Online Transition [4]. Organizational agility was tested during the pandemic [5], resulting in many institutions and faculty focusing on the rapid transition from physical to digital environments in place of necessarily considering online pedagogical strategies [4, 6]. The transition to online learning proved challenging for teachers as well as students due to a widening digital divide [7, 8], lack of self-regulation and engagement [9, 10], and mental health issues [11]. As a result of inadequate infrastructure, personal circumstances, and institutional/contextual factors, poor quality education provision and inequalities in access to education have emerged on a global scale [12–16].

Despite its pedagogical challenges, online teaching is becoming an increasingly important component of teaching and learning globally [17]. The HBLS is urged to realize effective innovation as a continuous process of designing and developing quality instructional events that promote competence-based, participatory and inclusive learning [18]. This study voices the students' point of view on the quality and accessibility of experienced HBLS in higher education.

2 Literature Background

The term hybrid education is commonly used to describe a balance between presence and distance in education. However, technology-enabled hybrid educational solutions not only integrate spatial elements (real or virtual), and communication modalities (synchronous and asynchronous), but also combine teaching strategies, as well as various materials, tools and resources to facilitate individual and/or collaborative learning [19]. The key to hybrid learning solutions lies not so much in the number of technologies utilized or the ratio of presence-to-distance instruction, but rather in how and why they are used [20]. Blended learning is a form of hybrid education that has been gaining popularity in higher education due to its ability to overcome various limitations associated with both online and face-to-face instruction [2]. Many different types of hybrid blended learning courses exist, from adding extra online activities to a traditional face-to-face course to developing the entire course as blended from scratch. In any case, it is imperative that hybrid blended solutions support collaborative, learner-centered instruction, as well as embedded assessment for learning in order to encourage innovative educational practices and meaningful learning [19].

Hybrid and blended learning solutions (HBLS) were boosted in recent times due to the advent of the Covid-19 pandemic. Online teaching, however, was often not the result of a well-considered instructional design process, rooted in a thorough needs analysis and inspired by the affordances of online education. Rather, this was an expedient response to an unexpected, unusually rapid, and poorly understood public health emergency [12, 14]. As a result, some undesirable effects of ICT adoption were amplified worldwide, such as inequalities in access to education caused by social, economic, and contextual factors [13, 14]. Globally, students in higher education experienced fatigue and concentration difficulties as a result of online education, as well as general dissatisfaction with the overall educational situation [21, 22].

The adoption of HBLS during the transition to online instruction needs to retain the good practices developed over the past decades, emphasizing, for example, flexibility in the teaching methods, assessment strategies, and temporal organization of the instruction [14, 22]. A number of advantages can be derived from HBLS in higher education, for example: addressing the need for flexible, personalized curricula [23, 24], providing differentiated instruction to meet the diversity of students [25], or improving student engagement with learning materials. As a result, HBLS may provide students with the freedom to learn at their own pace, at their own time, and in their own environment [24]. Such flexible approaches to learning are typical of individualized learning, in which students choose learning objectives and activities based on their cognitive and motivational characteristics [26]. Moreover, according to the IMS Global Learning Consortium [27], flexibility in quality education goes hand in hand with accessibility, as "accessibility is determined by the flexibility of the education environment and the availability of adequate alternative-but-equivalent content and activities".

In spite of this, the disengagement and dropout rates in these environments have raised concerns both over the years and in the most recent past [24, 28, 29]. Teachers and institutions should promote students' motivation to reduce dropout rates, starting with the alignment of the pedagogy and instructional environment with the needs and interests of the students, this can be achieved [30].

Accordingly, this study examines students' perceptions of the quality and accessibility of HBLS activated at their higher education institution. The results of this study will shed light on the needs and motivations of higher education students that HBLS should cater to in order to improve the educational experience.

3 The Present Study

The context of this study is a HBLS initiative in a master's degree course for teacher education, involving 680 student-teachers who attended a total of 21 HBLS courses and 112 HBLS group-based workshops (10% of total academic hours was online – [31], over the past 6 months (academic year 2021–2022). The research questions are:

How do higher education students perceive HBLS to foster accessibility in education?

How do higher education students perceive HBLS to foster quality in education?

3.1 Participants

An online survey circulated among the 680 student-teachers attending HBLS during the academic year 2021/2022, gathering 294 responses. Participation was anonymous and voluntary. Table 1 summarizes the demographics of the convenience sample.

Table 1. Sample characteristics.

Category	Variable	Raw frequency	% over tot (N = 294)
Gender	Male	13	4.4%
	Female	279	94.9%
	Other	2	0.7%
Highest title	High school diploma	231	78.6%
	Bachelor's degree	40	13.6%
	Master's degree	22	7.5%
	Other	1	0.3%
Role	Full time student	192	65.3%
	Part time worker	55	18.7%
	Full time worker	47	16%
Attendance at Higher Education institution	First year	68	23.1%
	Second year	93	31.6%
	Third year	62	21.1%
	Fourth year	50	17%
	Fifth year	21	7.1%
HBLS Participation	No participation	7	2.4%
	Partial participation	118	40.1%
	Full participation	169	57.5%

As per Table 1, among the respondents, 95% were female, and their average age was 23.5 years old (mode = 20, range = 28). Most participants attended their 2nd year at university (32%), but presence of all years (minimum 5th year, with 7% respondents). Most participants hold a high school diploma (79%) and are full-time students (65%), although a minority is a part-time (19%) or full-time (16%) student-worker. Only 2% did not participate in the HBL activities, while most participated either to part (40%) or all of the available ones (58%).

3.2 Methodology

The online survey comprised five sections:

A. *Demographics*: six multiple choice items on gender, age, year attended at university, role, highest title held, participation to HBLS activities;
B. *ICT integration at university* (Chronbach's alpha: .94): 13 5-point Likert scale items (1 = not at all capable; 5 = very capable) on the quality and accessibility of HBLS in higher education;
C. *HBLS courses/lectures* (Chronbach's alpha: .93): 12 5-point Likert scale items (1 = strongly disagree; 5 = strongly agree) and two open ended questions on the

quality and accessibility of HBLS strategies realized in the attended higher education courses/lectures;

D. *HBLS workshops* (Chronbach's alpha: .95): 11 5-point Likert scale items (1 = strongly disagree; 5 = strongly agree) and two open ended questions on the quality and accessibility of HBLS strategies realized in the attended higher education workshops;
E. Self-efficacy in ICT use (Chronbach's alpha: .91): 17 5-point Likert scale items (1 = not at all capable; 5 = very capable) and one open ended question on the self-assessed mastery of use of ICTs for HBLS.

The sections B-E were tested for reliability and were found more than acceptable. Moreover, exploratory factor analysis was carried out on the questionnaire to observe possible underpinnings for perceived quality and accessibility of HBLS in higher education. Table 2 shows the factors emerging through EFA, considering Eigenvalue > 1; varimax rotation and a principal component extraction method.

Table 2. Exploratory Factor Analysis on the online survey.

Factor	Items	Item example	Cronbach's alpha	Factor loadings
Quality of HBLS workshops	10	In the HBLS workshops, I experienced active, reflective, and collaborative methodological approaches	.95	.66–.77
Quality in HBLS courses/ lectures	11	In the HBLS lectures, the proposed face-to-face and remote activities were coherent and consistent with each other	.94	.51–.77
Access to HBLS in higher education	14	HBLS organization allowed me to balance study time with private or work life	.94	.49–.72
Self-efficacy for common ICT	8	I can use browsers like Explorer, Firefox, Chrome, Safari or others	.87	.63–.87
Self-efficacy for advanced ICT	9	I can use video editing software like Movie Maker, iMovie, Final Cut or others	.88	.57–.85

Factor 1 (*quality in HBL workshops*, Cronbach's alpha = .95) comprised 10 items that explained 21.97% of the variance with factor loadings from .66 to .77. Factor 2 (*quality in HBL courses/lectures*, alpha = .94) included 11 items that explained 20.48% of the variance with factor loadings from .51 to .77. Factor 3 (*accessibility of HBL in higher education,* alpha = .94) comprised 14 items that explained 20.74% of the variance with factor loadings from .49 to .72. Factor 4 (*self-efficacy for common ICT uses*, alpha = .87) included 8 items that explained 27.36% of the variance with factor loadings from .63 to .87. Factor 5 (*self-efficacy for advanced ICT uses*, alpha = .88) comprised 9 items that explained 29.40% of the variance with factor loadings from .57 to .85.

The five stable constructs resulting from the exploratory factor analysis were tested for reliability and deemed more than acceptable [32].

4 Findings

4.1 HE Students' Experience with HBLS

Descriptive statistics were run on the five constructs for the whole population (Table 3). In general, participants fairly valued the experiences with HBLS in higher education.

Table 3. Descriptive statistics on five factors, pooled sample (N = 294).

Factor	N	Mean	Std. Deviation	Mode	Median	Min-Max
Quality of HBLS workshops	294	3.70	.96	5	3.80	1–5
Quality in HBLS courses/lectures	294	3.49	.92	5	3.58	1–5
Access to HBLS in higher education	294	3.83	.83	5	3.93	1–5
Self-efficacy for common ICT	294	4.35	.58	5	4.50	2–5
Self-efficacy for advanced ICT	294	2.88	.82	3	2.78	1–5

Overall, participants well appreciated the **quality of HBLS in workshops**, with a mean of 3.70 on the 5-point Likert scale (st.d. = .96 – Table 3).

The most appreciated aspects relate to the impact of HBLS workshops on the *organization of attendance* (item 26- mean = 3.97, st.d. = 1.18); and to the *coherence between face-to-face and digital activities* (item 33- mean = 3.88, st.d. = 1.03). Among the least appreciated, but still in the middle of the Likert scale, there is item 30 that reads: *"BL workshop activities facilitating sharing the tasks with peers in the group"* (mean = 3.22, st.d. = 1.09).

Moreover, participants fairly valued the **quality of HBLS in lecture/courses**, with a mean of 3.49 on the 5-point Likert scale (st.d. = .92). The most appreciated aspects concerned the *use of HBLS to challenge one's learning through exercises* (item 2 - mean = 3.83, st.d. = 1.03); and the *chances for collaborative works* (mean = 3.73, st.d. =

1.14). Among the least appreciated in this factor, but still in the middle of the Likert scale, there is item 10, which reads: *"digital environments (e.g. Moodle) help students communicate between themselves"* (mean = 3.21, st.d. = 1.28).

Access to HBLS in higher education scored quite high on the scale, with a mean at 3.83 (st.d. = .83). The items within this factor with the highest appreciation were number 13 ("*knowing how to explore the web helps students to find information useful in developing effectively their own learning"*), with a mean of 4.29, st.d. = .87; and number 14 *("BL experiences help me organize better study time")* with a mean of 3.90, st.d. = 1.18.

The *communication between students and educators* (item 11) was among the least appreciated in this area (mean = 3.50, st.d. = 1.19).

Overall, participants' **self-efficacy** on the use of more common technologies is very good (mean = 4.35 out of 5, st.d. = .58), while they are less confident on the use of more advanced technologies (mean = 2.88 out of 5, st.d. = .82).

4.2 Patterns of HBLS Appreciation for Accessibility and Quality

A two-step cluster analysis was then performed in SPSS(27) to explore patterns of responses among the participants. Three patterns emerged, displaying peculiar perceptions of HBLS in higher education. A first pattern related to those who expressed an *enthusiastic* appreciation of the quality and accessibility of HBLS in higher education, grouping 82 of the respondents (29%). Another 125 respondents (44%) demonstrated a *good* appreciation of HBLS in higher education, while 77 (27%) were *dismissive* of the quality and accessibility experienced (Table 4, Fig. 1).

Overall, the three clusters were very different on every construct (ANOVA, $p < .001$). They were most dissimilar on the perception of *access to HBLS in higher education* ($\eta^2 = .70$, beyond large effect size according to [33]); on the *quality of HBLS courses* ($\eta^2 = .67$, beyond large effect size); and on the *quality of HBLS workshops* ($\eta^2 = .64$, beyond large effect size). They were the least different, although still significantly ($p < .001$), on *self-efficacy for common ICT use* ($\eta^2 = .18$, still large size effect according to [33]) and on *self-efficacy for advanced ICT use* ($\eta^2 = .25$, large effect size).

Variables such as gender, age, year of attendance, or degree of participation in HBLS activities did not determine the affiliation to one group or another (ANOVA, $p < .05$). In contrast, the highest title held and being a student/worker influenced group membership ($p < .05$).

A description of the individual patterns, i.e. profiles, in relation to the 5 factors of the questionnaire follows.

The first cluster groups 82 students with *enthusiastic* appreciation of the experienced HBLS (Table 4, Fig. 1). They are among the oldest respondents (25 years old on average), and mostly female, although a third of all the male respondents gather here too (31% overall). This group also gathered the highest relative percentage of students holding bachelor's (49%) and master's (55%) degrees, as well as the highest relative percentages of part-time and full-time workers (respectively, 49% and 39% of the respondents in those categories). Almost half (40%) attended their second year at university and they were either partially or completely participating to HBLS activities (respectively, 35% and 63%). They displayed a great appreciation of the quality of HBLS courses (mean = 4.38,

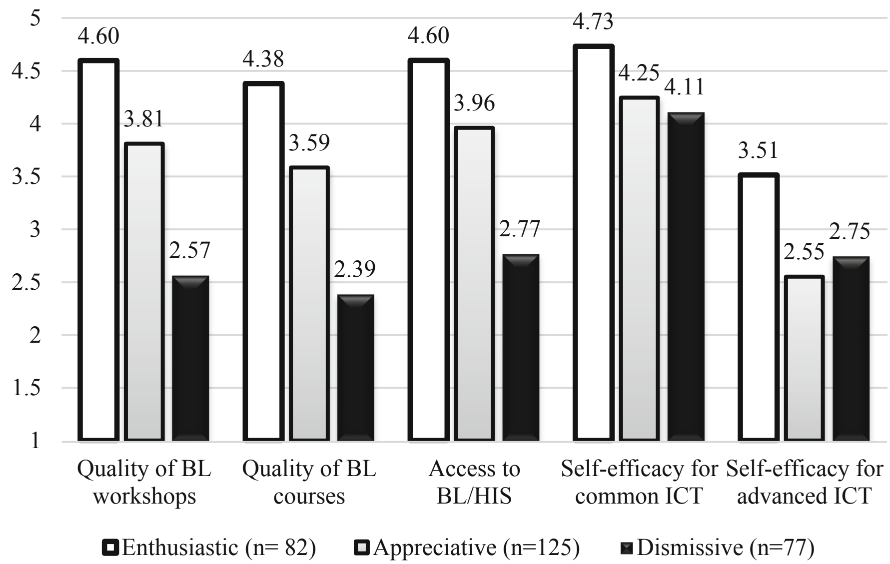

Fig. 1. Patterns of answers by the three clusters of students' perceptions (means).

Table 4. Demographics for the three clusters (i.e. profiles) of students' perceptions.

Category	Variable	Raw frequency (% over tot N = 294)			Invalid data (% over tot N = 294)
		Enthusiastic (n = 82)	Appreciative (n = 125)	Dismissive (n = 77)	
Gender	Male	4 (30.8%)	7 (53.8%)	2 (15.4%)	
	Female	77 (27.6%)	117 (41.9%)	75 (26.9%)	10 (3.6%)
	Other	1 (50%)	1 (50%)		
Highest title	High school diploma	51 (22.1%)	103 (44.6%)	68 (29.4%)	9 (3.9%)
	Bachelor's degree	19 (47.5%)	14 (35%)	6 (15%)	1 (2.5%)
	Master's degree	12 (54.5%)	8 (36.4%)	2 (9.1%)	
	Other			1 (100%)	
Role	Full time student	39 (20.3%)	85 (44.3%)	61 (31.8%)	7 (3.6%)
	Part time worker	21 (38.2%)	26 (47.3%)	7 (12.7%)	1 (1.8%)

(*continued*)

Table 4. (*continued*)

Category	Variable	Raw frequency (% over tot N = 294)			Invalid data (% over tot N = 294)
		Enthusiastic (n = 82)	Appreciative (n = 125)	Dismissive (n = 77)	
	Full time worker	22 (46.8%)	14 (29.8%)	9 (19.1%)	2 (4.3%)
Attendance at Higher Education institution	First year	14 (20.6%)	30 (44.1%)	20 (29.4%)	4 (5.9%)
	Second year	33 (35.5%)	34 (36.6%)	25 (26.9%)	1 (1.1%)
	Third year	21 (33.9%)	26 (41.9%)	15 (24.2%)	
	Fourth year	12 (24%)	25 (50%)	12 (24%)	1 (2%)
	Fifth year	2 (9.5%)	10 (47.6%)	5 (23.8%)	4 (19%)
HBLS Participation	No participation	1 (14.3%)	5 (71.4%)	1 (14.3%)	
	Partial participation	29 (24.6%)	49 (41.5%)	36 (30.5%)	4 (3.4%)
	Full participation	52 (30.8%)	71 (42%)	40 (23.7%)	6 (3.6%)

st.d. = .55) and workshops (mean = 4.60, st.d. = .50), as well as of the accessibility provided (mean = 4.60, st.d. = .39 - see Table 3 and Fig. 1). Their self-efficacy for common ICT uses was very good (mean = 4.73, st.d. = .33) and above average for advanced ICT uses (mean = 3.51, st.d. = .77).

The second cluster groups 125 students displaying *medium appreciation* of the experienced HBLS. They are 23 years old on average, mostly female (94%) but still gathering more than half of the total number of male respondents (7, namely the 54%). The vast majority is a high school graduate (82%), although 36% of the students with previous bachelor's or master's degrees also gather in this group. Similar rates of students in this cluster attended the first (24%), second (27%), third (21%) or fourth (20%) year at university, and were mostly full-time students (85%). Noticeably, half of the part-time students also participate to this cluster (48%). Finally, this group has the highest ratio of students not/partly participating to the HBLS activities (respectively 71% and 43% of the respondents in those categories) to the ones fully participating (43% of the total). They displayed a good appreciation of the quality of HBLS courses (mean = 3.59, st.d. = .48) and workshops (mean = 3.81, st.d. = .57), as well as of the accessibility provided (mean = 3.96, st.d. = .43 - see Table 2 and Fig. 1). Their self-efficacy for common ICT uses was very good (mean = 4.25, st.d. = .42) and but below average for advanced ICT uses (mean = 2.55, st.d. = .58).

The third cluster groups 77 students with *dismissive* about the quality of and access to HBLS in higher education. They are among the youngest respondents (22 years old on average), mostly female (97%). Most of these respondents have a high school diplo-ma as their highest title (88%) and are full-time students (79%) at their first or second of university (26% and 33% respectively). This cluster gathers the lowest ratio of students fully participating to partially participating to HBLS activities (52% to 47%). They displayed the lowest appreciation of the quality of HBLS courses (mean = 2.39, st.d. = .59) and workshops (mean = 2.57, st.d. = .67), as well as of the accessibility provided (mean = 2.77, st.d. = .55 - see Table 2 and Fig. 1). Their self-efficacy for common ICT uses was quite good (mean = 4.11, st.d. = .78) and but still below average for advanced ICT uses (mean = 2.75, st.d. = .83).

5 Discussion and Conclusions

This study focused on the educational quality and accessibility provided by HBLS at the higher education level, as perceived by the primary protagonists of education: the students. Overall, the surveyed students showed good appreciation for the quality and accessibility of the experienced HBLS (see Table 3) – although we need to account for a certain degree of answer desirability. This is in line with other recent studies like Silletti and colleagues' [21] on student appreciation of forms of distance learning.

Three patterns of response, i.e. cluster profiles, emerged from deeper data analysis. The *enthusiastic*, *appreciative*, and *dismissive* clusters showed peculiar levels of recognition of the quality and accessibility of the experienced HBLS. The degree to which students value HBLS may connect with their motivation and engagement in instruction, and their intention to persist [24, 34].

Moreover, cluster affiliation differed according to the highest title held and being a student/worker, whilst gender, age and seniority at university proved irrelevant to that. This finding suggests different typologies of students with possibly different educational needs and expectations that affect their assessment of the higher education offered. We found that the degree of participation was not significantly different across the profiles, which requires further investigation. A possible explanation for this could be in the adopted teaching methodologies/strategies: if they were the same face-to-face and remote, it is possible that the HBLS appreciation data would not fluctuate according to participation. This hypothesis is supported by research testifying how many faculty simply transpose analogue teaching methodologies/strategies digitally [12, 14, 22]. Future research could focus on the teaching methodologies and strategies implemented, to possibly better understand this finding.

Teachers and institutions can use the findings to conduct in depth discussions with their students about their interests and perceptions in order to accommodate their needs and improve educational quality and access (see also [24]). In order to support students effectively, institutions should develop a vision and guidelines for supporting them without restricting their flexibility. In order to benefit and support diverse learners, the institution should use the profiles to follow up on students and find out how to improve their education (as suggested by similar studies by, among others, [24]). There may be an opportunity to differentiate attendance modes based on the educational objectives, as suggested by Zucchermaglio and colleagues [22], and to implement more flexible forms of instructional design and assessment.

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The Inclusive Design of a Learning Path with Integrated Digital Teaching in the Education Science Degree Course at the University of Genoa

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Abstract. The contribution presents the results of an exploratory survey conducted with 135 students attending the courses of Special Pedagogy (92 students) and Inclusive Didactics (43 students). The courses were in the Degree Course in Education Sciences of the University of Genoa in the academic year 2021–2022. The aim of the survey was to measure: how the inclusive design, of these two courses, influences the personalization of the learning path and it increases the process of self-regulation and self-efficacy of students. These paths have developed through the application of face-to-face teaching, but during the lessons these courses were enriched by paths on digital platform. The improvement of abovementioned two aspects allows a better reworking of learning content. Two questions were used to collect students' points of view: the Self-regulated Knowledge Scale University (SRKS-U) [1, 2], in Italian Version Sara-U [2], and the Perceived School Self-Efficacy Scale [3, 29] adapted and integrated with requests for explanation of students' choices. The results obtained from the analysis of the questionnaires are encouraging and invite teachers to reflect on the possibility of applying mixed teaching methods within their teachings on a daily basis.

Keywords: Personalization · Self-regulation · Integrated digital teaching

1 Introduction

Following the provisions on the methods of delivery of university courses issued at the Ministerial level to gradually restore a return in the presence of lectures, the University of Genoa, like many other universities, has established, up to the persistence of the state of emergency linked to the pandemic by Covid 19, the activation of Integrated Digital Teaching.

The application of the Integrated Digital Teaching has offered to teachers, the opportunity to experiment with the potential of technologies. During the delivery of their course, technologies favored: the active participation of all students, the development of

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their self-regulatory and self-efficacy capacities, the use of diversified methodologies of active didactic and innovative forms with which to propose self-assessment courses to students from a training perspective.

These aspects are fundamental in an inclusive perspective, that focuses on the importance of structuring personalized learning paths aimed at self-regulation, in order to ensure easy access to knowledge content even for students with a special educational need (SEN). In inclusive training courses, personalization is fundamental, because it allows each student to choose the path of acquiring knowledge starting from their own set of skills.

Starting from these observations, the contribution presents the results of an exploratory survey conducted with 135 students attending the courses of Special Pedagogy (92 students) and Inclusive Didactics (43 students) in the Degree Course in Education Sciences of the University of Genoa in the academic year 2021–2022 aimed at detecting the trend of students' perceptions with respect to their ability to self-regulate and show themselves self-effective during the development of the modules organized through Integrated Digital Teaching.

2 Theoretical Framework

The use of tools and technological applications amplifies the perception in students of a greater possibility of choosing the learning path to follow. This is a fundamental element for starting the self-regulation [4, 5] process and self-efficacy process [6, 7]. It describes as a metacognitive dimension in which the student independently manages his/her own learning path from a motivational and behavioral point of view [8–10]. The autonomous management of own learning can get greater success in learning design. This management effects positively on the sense of self-efficacy. Studies [11, 12] show that the use of learning strategies functioning to one's own cognitive style, can support the achievement of learning objectives, with greater probability of success. All that has a positive impact on the sense of self-efficacy.

The use of technological devices and applications develops the dimensions connected to self-regulation and self-efficacy [5–7, 13]. It offers to students the possibility to control these dimensions by adapting their skills and abilities, to the learning environment and more likely to experiment success in performance [5, 13].

However, to increase the processes of personalization and self-regulation in learning, it is not enough to introduce technology or use a technological learning environment, but an effective didactic design is essential. The teacher designs his/her didactic intervention with technologies, according to the objectives to achieve. He or she must know how to combine the technology (tools, applications, and environments); the methodologies and strategies (cooperative learning, problem-based learning, flipped lessons); the critical reflection (sharing of points of view, comparison of ideas); the content and evaluation (feedback, self-evaluation) [14]. For example, in cooperative learning, one objective is the development of critical thinking. So the use of shared tool is appropriate, because it allows discussion of ideas among the students. This doesn't happen in the use of a traditional methodology. Furthermore, to ensure a quality training experience, it is essential to constantly issue adequate feedback from teachers and learning companions [14–16] which refers to the formative dimension of evaluation.

2.1 Designing the Technological Learning Environment

The "technological environment" is characterized by the presence of multiple media, applications, tools and the possibility of actively operating with them and on them. As it described in a previous contribution [17, 18], it is possible to discern the technological learning environments in:

- *Technological environments in presence* in which technological instruments (such as the Interactive Whiteboard, the tablet, the smartphone or the PC) are used with a purpose of use and/or production of knowledge material. For example, students can use these technologies to search new information, to create specific products requested by the teacher during the lessons. In these environments other applications are used, such as Wooclap for the management of formative evaluation processes, brainstorming, shared analysis (of videos, for example) in which the anonymity of the answers motivates the enlarged participation of students [14, 19].
- *Technological environments of distance learning*, where the environment simultaneously can become the tool and methodology of use [5]. When there is a didactic planning by the teacher and therefore an educational intent, the link between technology and methodology is created. [20–22]. In these environments are used: Learning Management System (LMS) platforms such as Moodle, Classroom that allow you to insert the contents of the lessons, propose activities, requests the solution of authentic tasks even in asynchronous collaborative mode (for example through the use of wikis); manage formative assessment paths (through the provision of feedback e.g. through forums). Students can use virtual bulletin boards such as Padlet (for collaborative knowledge building, personalization of learning, brainstorming and online tutoring). LMS are frequently associated with the use of communication platforms such as Teams, Meet, G-Suite where it is possible not only to interact in a frontal way but also to organize collaborative work groups in synchronous.
- *Virtual learning technological environments*, i.e. 3D digital environments (such as Edmondo), in which an avatar can trigger exploration processes, propose lessons and presentations, meet, collaborate and view the materials of other users. [23, 24].

In relation to the self-regulation of the learning process by students, the forms of mixed teaching (presence and distance) require considering elements that were not considered of great importance for self-regulation in the traditional learning modality [10].

The online self-regulation model presented by Barnard and collaborators [25] proposes to consider: the structuring of the environment, the definition of objectives, time management, the search for help, strategies to be applied to tasks and self-assessment [10, 25].

The next approaches believe that determining factors for self-regulated learning in the online environment are: metacognitive perspective, time management, effort regulation, peer learning, processing, testing, organization, critical thinking, seeking help [10, 26].

2.2 Self-regulation in Remote Technological Environments

The preparation of technological learning environments, in the three forms previously analysed, highlights the usefulness of technologies. They are used: to organize personalized learning paths (in managing study materials and in facilitating interactions between learners and the teacher); to support engagement of the learner in an adaptable path, also from an organizational point of view [14].

Using an LMS (e.g. Moodle or Classroom) or a Padlet allows you to personalize the learning process. This use can encourage the development of self-regulation, but also of self-determination. It becomes possible to prepare lessons that can follow with different paths. Students can: create group activities (synchronous or asynchronous), prepare activity reports and/or research, realise a personal e-portfolio for each student, manage a discussion, insert resources such as word files, pdfs, videos, link to other applications, resources and software. Fundamentals of constructivism appear from these activities, in agreement with the assumptions of the development of self-regulation. According to this school of thought, everyone builds their own knowledge through critical comparison and exchange of points of view, in the interaction that stimulates the activation of higher order cognitive processes.

Social dynamics (exchange of feedback, comparison with the work of others) support the self-regulation of learning on the metacognitive level (as they stimulate a reflection on one's own learning) and on the motivational/emotional one (as they provide the subject who learns a means to find comfort and help in cases of difficulty or blockage) [5]. The access to online materials at any time and as often as desired, increases students' level of movement [27], the level of cognition and thinking that results in progress in performance [14, 28].

Students can find all the useful materials to development and following lessons and tasks. They can use them in ways that are more appropriate to one's own learning style. It's also possible to consult the works of their classmates on the platform. This is an added value for the development of self-regulation, because it allows us to understand if the task has been done correctly [14].

A further useful element for self-regulation is represented by the possibility of asking the teacher, through the tools of a platform, questions with respect to unclear elements [14] or trying to intervene to answer the teacher's questions (presented for example with Wooclap) and self-verify what he has learned. The possibility of having personalized feedback is undoubtedly useful for self-regulation [29].

Even the way in which it is decided to propose the contents is fundamental to ensure greater self-direction in learning, for example, by organizing them by modules and not on the single lesson [14].

At the beginning of each module it would be necessary to indicate the prerequisites necessary to perform a task [5]: this influences the behaviour, because it makes you understand what is expected of that activity and, therefore, prepare adequately. It also has an impact on motivation, as it helps a correct attribution of successes or failures obtained [5, 8].

Each module should also propose different levels of complexity and depth of content in the learning environment. This determines a relapse on the metacognitive and motivational level: "on the one hand it forces the learner to take note of the degree of learning achieved to choose the most suitable level for his preparation, on the other hand it can help him manage his motivation, providing partial objectives that are easier to tackle" [5].

As regards the organization of each module, as Bevilacqua claims, this should include: the consultation of preliminary materials, the response to feedback, the resumption of contents in the classroom, the performance of the authentic task, a moment of self-assessment and present the same time scan for the entire duration of the course. This allows students to increase awareness in dealing with authentic tasks and to decrease perceived disorientation with respect to the greater learning flexibility guaranteed to them [14].

3 Methodology and Data Analysis Tools

Starting from these observations, an exploratory survey was conducted with 135 students attending the courses of Special Education (92 students) and Inclusive Didactics (43 students) in the Degree Course in Educational Sciences of the University of Genoa in the academic year 2021–2022. The same teacher developed these two courses that were carried out in the same semester. Students attended all modules of a course (Special Education or Inclusive Didactics). Every module was strictly connected to one another. The objective of the survey was to detect how the inclusive design of the learning paths of the two courses, through the application of digital teaching, has influenced: (1) the personalization of the students' learning path and (2) it has increased the process of self-regulation and student self-efficacy allowing for better reworking of learning content. Our research questions are: according to the principles of integrated digital teaching, can the design of a course increase the process of self-regulation and self-efficacy in students? Can this method promote greater accessibility to the students' learning path from an inclusive point of view?

The choice of technological learning environments and the way we decided to organize the course, followed the indications in the literature, as explained in the following paragraphs.

3.1 Technological Environments Used

Three types of integrated learning environments were used following the indications of the literature: (1) Environments in presence (i.e. the physical class); (2) Interactive and synchronous environment (i.e. the Teams platform), connected with the presence environment also thanks to the use of applications such as Wooclap for the management of formative assessment processes, the brainstorming and shared analysis (of videos, for example) and Kahoot in which the anonymity of the answers motivated the extended participation of the students [14, 19]; (3) Asynchronous interactive environment (i.e. the Moodle platform) a Learning Management System (LMS) necessary to insert the lesson modules, propose activities, request the resolution of authentic tasks even in asynchronous collaborative mode (for example through the use of wiki); manage formative evaluation paths (through the provision of feedback, for example through forums); connect to virtual message boards such as Padlet (for the collaborative construction of knowledge, the personalization of learning, the braistorming and online tutoring).

3.2 The Organization of the Course

Regarding the organization of the course contents, the partition of the course in modules and not by a single lesson [14] was chosen, to ensure greater personalization and self-regulation of learning. Each module has been implemented in the Moodle platform and organized internally with the indication of the expected objectives, the contents, and the activities to be carried out (in Moodle), the required prerequisites, necessary to support the understanding of what the student could expect from each module thus allowing him a correct attribution of any successes or failures he would have obtained [5, 8].

Each module has provided the same time frame and different materials within it, such as preliminary documents for the meeting with the teacher, "task sections" with diversified activities chosen by the student, links to videos, links to Padlet to structure personalized paths, wiki for collaborative writing, audio of the lessons downloaded from the Teams platform, interaction forum between classmates and teacher.

3.3 Data Collection Tools

At the end of each module, two questionnaires were used in previous research on self-regulation and motivation of university students traceable in the literature [2, 29]: (1) the Self-regulated Knowledge Scale University (SRKS-U) [1, 2], in Italian Version Sara-U [2], in order to measure the frequency with which students have implemented different cognitive strategies in relation to different tasks and technological applications; (2) the perceived school self-efficacy scale [3, 29] to analyze the students' beliefs about their ability to regulate their motivation to study according to the different requests.

The SARA-U consists of five subscales that want to answer this question "When do you study, how often do you do the following things?" to detect the use in students of the strategic cognitive processes shown in the following table (Table 1):

Table 1. Strategic cognitive processes investigated by SARA-U [2, 29]

Extrapolation of knowledge	How often the information that is considered most important is selected
Linking knowledge	How often new knowledge is linked to knowledge already possessed
Use of knowledge	How often knowledge is used
Knowledge criticism	Frequency about we criticize what we have learned and formulate new ideas
Knowledge monitoring	Frequency with which the progress of one's knowledge is checked

The items are in total 15 and a 5-step scale is used (1 = Never; 2 = Rarely; 3 = Sometimes; 4 = Often; 5 = Always) to express the preference (Table 2).

Table 2. SARA-U items with "5 levels" scale [2, 29]

	Never	Rarely	Sometimes	Often	Always
1. I summarize the most important things					
2. I look for similarities or differences between what I'm studying and what I already know					
3. I repeat to myself several times the important things to learn					
4. I wonder if I agree with what I read in books or with what is said in class					
5. I'll check if I understand correctly what I'm reading					
6. I write the most important concepts of a particular topic that I study					
7. I look for links between the different subjects I study					
8. I see myself several times a topic if I want to learn it well					
9. I try to get my own personal idea about the things that I study					
10. I check which part of a topic to be studied I still do not know well					
11. I make diagrams or maps of the most important topics					
12. I try to see how it connects what I'm studying with what I already know					
13. I often repeat the most important concepts to memorize them better					
14. I try to make criticisms or to put in discussion what I find in books					
15. I try to make sure I understand well what I'm studying					

As far as the Perceived School Self-efficacy scale is concerned, it was used in a further reduced version compared to that proposed by Biasi and collaborators [30] and focused on 6 items instead of 9.

The answer alternatives considered are those highlighted below (Table 3): 1 = not at all capable; 2 = incapable; 3 = quite capable; 4 = very capable; 5 = fully capable by adapting the items in relation to each proposed module [30].

Table 3. Item and alternative answers for Perceived School Self-efficacy adapted [3, 29]

	Not at all capable	Not very capable	Able enough	A lot able	Absolutely Able
1 To finish module tasks on time					
2 To engage in studying the module when you have other interesting things to do					
3 To focus on studying without getting distracted					
4 To take notes during lectures					
5 To remember what is explained in class and what you have read in the books					
6 To be interested in the topics covered by the form					

The questionnaires were written in the Google Form application and administered online to students.

Students were given the opportunity to add personal comments to the questions of the questionnaires in order to enrich the quantitative data with the qualitative ones that allowed to grasp the motivations of the answers provided.

4 Results

The data analysis highlighted the positions expressed by the students about on the experience undertaken. The results demonstrate a positive opinion about on personalization in an inclusive perspective of the organization of the courses presented. They describe greater personalization to subjects of courses, because students followed their pace and personal learning times.

The following table (Table 4), shows the results obtained in the first administration of the SARA-U questionnaire carried out at the end of the first module. You can see also the results obtained at the end of the administration carried out at the end of the last module after about 2 months. See Table 2 for the items.

Table 4. Results of the first and last administration of SARA-U

	Never		Rarely		Sometimes		Often		Always	
	Start	End	Start	End	Start	End	Start	End	Start	End
Item 1	6%	4%	12%	10%	42%	26%	25%	38%	15%	22%
Item 2	0%	0%	12%	5%	38%	28%	29%	38%	21%	29%
Item 3	2%	0%	9%	5%	42%	30%	29%	39%	18%	26%
Item 4	8%	4%	14%	9%	38%	26%	25%	34%	15%	27%
Item 5	0%	0%	5%	1%	25%	25%	30%	33%	40%	41%
Item 6	9%	5%	15%	10%	36%	30%	25%	35%	15%	20%
Item 7	12%	6%	20%	9%	38%	34%	20%	30%	10%	21%
Item 8	4%	0%	12%	8%	44%	48%	28%	30%	12%	14%
Item 9	5%	1%	8%	7%	36%	29%	28%	34%	23%	29%
Item 10	0%	0%	5%	1%	25%	16%	38%	44%	32%	39%
Item 11	0%	0%	1%	0%	35%	21%	33%	40%	31%	39%
Item 12	4%	1%	9%	5%	37%	23%	38%	49%	12%	22%
Item 13	5%	1%	11%	4%	39%	29%	26%	36%	19%	30%
Item 14	13%	8%	25%	14%	31%	28%	20%	31%	11%	19%
Item 15	1%	0%	7%	6%	41%	34%	28%	32%	23%	28%

As well highlighted, there is an increase in positive responses for all items. It is interesting a significant increase in the strategic dimension (item 2 6,7 10,11, 12) and in the critical dimension to knowledge processing (items 4, 9, 14) in the approach to the various parts of the lesson modules.

In general, the answers provided to the items of the SARA-U questionnaire allow to detect an increase in the use of cognitive strategies such as (1) the selection of relevant information, (2) the search for a link between knowledge already possessed, (4) the practical application of what has been learned, (5) common critical reflection and (6) the generation of new ideas.

The table above (Table 5) shows the results of the application of the Adapted Perceived School Self-Efficacy Scale as previously explained. It is possible to see that the increase in the dimensions related to self-determination follows an increase in specific aspects of self-efficacy. See Table 3 for the items.

In particular: (1) feeling more able to finish in time what is proposed in the various modules and (2) being able to control the levels of concentration both in the explanation of the teacher and in the moment of practical work. Linked to these elements also emerge (1) a greater ability to remember and make one's own what has been learned and (2) an increase in interest in the contents of the proposed modules.

Table 5. Results of the first and last administration of the Perceived School Self-Efficacy Scale (taken and modified by [3, 29]).

	Not at all capable		Not very capable		Able enough		A lot able		Absolutely Able	
	Start	End	Start	End	Start	End	Start	End	Start	End
Item 1	6%	2%	14%	9%	43%	35%	25%	31%	12%	23%
Item 2	13%	10%	14%	11%	33%	25%	25%	30%	15%	24%
Item 3	0%	0%	12%	9%	48%	41%	26%	30%	14%	20%
Item 4	4%	2%	9%	5%	45%	31%	20%	39%	22%	23%
Item 5	0%	0%	2%	2%	53%	36%	25%	38%	20%	24%
Item 6	2%	2%	3%	3%	38%	18%	34%	39%	23%	38%

5 Conclusion

The results allow to answer positively to the first research question. The course, organized according to principles of integrated digital teaching, has shown to increase the sense of self-regulation and self-efficacy. Students consider the following aspects important, because they seem to have increased these two dimensions: the possibility of participating in presence and on line, intervening by using applications such as Wooclap, Kahoot by receiving immediate feedback and integrated with the explanations of the teachers; listening to the lessons recorded, thinking about unclear points being able to analyze the interventions of classmates during the lessons, working in a collaborative way (synchronous and asynchronous) by comparing themselves with companions on the different contents. These are some of the elements that seem had a positive effect on the sense of self-regulation and self-efficacy for students. [31–33].

About on our second research question, students declare that they have perceived an increase in the level of personalization of the learning path. In this way the students have found a greater correspondence with their own styles, needs and rhythms of learning. This aspect is strictly connected and it acted positively on the on the sense of auto-regulation and self-efficacy [33]. An increase in the perception of self-regulation and self-efficacy is considered essential for reworking content, managing study materials and maintaining commitment and concentration at high levels. [33].

The number and types of strategies adopted by the students were varied in relation to the purposes of the different modules and the demands of the activities and applications used. An important element emerged from the analysis of the data: at the beginning of courses some students said verbally that they had a lot of difficult on management of self-regulation and self-efficacy. We can see from analysis of data that the students found help in this organization of the course about on self-regulation and self-efficacy. Indeed they perceived a very important support for these elements: the availability of constant feedback issued by both teachers and classmates; for the greater possibility of interacting, reflecting and exchanging opinions with peers on the correct ways of dealing with a learning content.

These encouraging results lead us to think of enhancing some aspects studied here. The potential of teaching methods applied to new technologies still opens new questions and pushes us to develop new studies in order to further promote the learning of our students.

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A Methodological Framework to Cultivate Transformative Learning in Faculty Development

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Abstract. Object: The chapter presents the first results of an exploratory study on faculty perspective transformations due to the massive shift to blended learning after the pandemic of Covid-19.

Aims: The aim is to explore how faculty development can be informed by transformative and informal learning when facilitated through the set of communities of practice and focused on perspective transformation in time of disruptive changes like the post-pandemic one.

Conceptual Framework: The conceptual framework included the international literature on faculty development, faculty community of learning, and collaborative research in HEIs.

Methodology: The research design is an exploratory study. Faculty, institutional and managerial actors, Directors of Centers for Teaching & Learning took part in the research. Data collection was carried out through 35 in depth interviews and 8 focus-groups.

Results: Results allowed to formalize a model to respond to the new challenges of the post-Covid 19 university: the 4S model to faculty development, where the 4S is the acronym for Sociocracy, Space, Sustainability and Share dimensions of faculty development.

Implications: The final section includes recommendations on ways for HEIs to support faculty engagement in communities of practice.

Keywords: Community-based learning · Faculty development · Transformative learning · Informal learning · Community of practice · Covid-19

1 Crossing the Crisis. The Disorienting Dilemma Produced by the Covid-19 Outbreak

Since the beginning of the pandemic, much of the focus of research and press around the impacts to Higher Education Institutions (HEIS) have been centered on institutional actions, organizational changes, faculty and student response to the disruption that Covid-19 wreaked on teaching experience [2]. The Covid-19 outbreak magnified inadequacies

"The transformation of teaching must start within the transformed heart of the teacher" [1, p. 107].

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structurally present in the Higher Education systems since many HEIs worldwide were forced to change their mode of operation [3]. Due to several waves of pandemic, the government imposed huge prevention measures, such as lockdown, "stay home" orders, and rapid shift to online teaching [2]. Emergency remote teaching [4, 5] became the prevalent modality of keeping teaching continuity from all over the world. The dramatic alteration in how HEIs functions "were delivered was not perfect or error free, and was complicated by the confluence of psychological, resource, and health-related challenges that affected students" [2, p. 13], faculty and instructors.

If at the beginning the pandemic generated collective disorientation and fears, the "endemization" of the pandemic had profoundly changed the organizational management system for teaching in HEIs, and probably the perceptions of teaching. It disrupted routines and habits that faculty used to practice in their daily life and that may not be part of the "new normal" that is emerging [5].

When Covid-19 outbreak hit, traditional "in-person" lectures became impossible. Technical, pedagogical, and organizational issues came up and the main concerns were about avoiding drop out of students' and ensuring teaching continuity [6, 7]. Universities were unprepared to face this rapid shift to remote instruction: faculty with a minimal training had to quickly become familiar with online pedagogy and the technological infrastructures to teach courses remotely [2]. Nevertheless, faculty with prior training on blended teaching or with an open mind to technology enhanced learning (TEL) were prone to change their instructional approach [8]. These faculty considered the massive shift toward online teaching as a stimulus for confronting with new challenges and rethink how to embed new methodologies and tools in their courses [2]. Against those, groups of faculties assumed polarized positions against the online teaching, contesting that permanent online teaching determined lack of emotional presence, poorness of attention, and impairment in student learning [9, 10].

The transformations galvanized by the pandemic increased exponentially the diffusion of flexible methods of course delivery. Blended learning, hybrid learning, flexible learning, were the most popular orientation for the courses due to the multiple and flexible opportunities provided for people engaged in lifelong learning, regardless of geographic location (place-independent), theoretically available 24 h a day (time-independent), and reducing feeling of discriminations for gender, race, economic status, special needs, learning gaps [11]. Those defined as positive aspects of online education required faculty to address technologically enhanced teaching, students' expectations of high levels of content personalization and adaptive learning, and new framework to conceptualize professional development for the competence of "2022" faculty [6, 12, 13]. According to this scenario, the article depicts an exploratory study on faculty perspective transformations due to the massive shift to online and blended learning during and after the pandemic of Covid-19. The following paragraphs outline:

a. an overview of the implications of the transformative learning for faculty development;
b. methods and findings of the exploratory study, which provides insight into how faculty development can be informed by transformative and informal learning when facilitated through the set of community of practices that could act as a leverage for innovation in organizations;

c. conclusive reflections on the construction of a transformative framework for faculty development formalized in the 4S Model.

2 The Transformative Learning Theory and Faculty Development

The literature framework that underpins this chapter is rooted in the field of faculty development [14, 15], motivation to engage in faculty perspective transformation [16, 17], and empirical research on the conditions for the development of faculty communities of learning [18, 19], and communities of practice [20]. This empirical framework about faculty development is combined and intertwined with a conceptual framework nurtured by contributions from the adult learning field, such as transformative learning theory [21, 22], informal and incidental learning [23], and practice-based studies [20, 24].

Those approaches explore the type of knowledge sharing that informally and incidentally happen in the faculty exchanges in groups, communities of learning and communities of practice. Moreover, they focus on the transformational experiences faculty can undergo, and on their impact on the change of professional epistemologies [1, 25, 26]. Transformative learning theory, as conceptualized by Mezirow [21] refers to how individuals, groups, and communities, can identify ideas, beliefs, values, and feelings that are, for the most part, uncritically acquired, and validate the source for their culturally assimilated perspectives. Those tacit structures can restrict people's ability to produce new habits, and adaptive changes [21]. The input of transformative learning theory to faculty development offers renovated trajectories to understand how to cultivate critical reflection processes in HEIs and what type of professional development paths have the potential to stimulate self-critical reflection in faculty, professors, and students.

Particularly, in the transformative learning theory, meaning perspective transformation is portrayed as a process by which adult people discover determinants of their thoughts, feelings, and actions, which may have been at work unconsciously [27]. This discovery is often elicited by a disorienting dilemma, an external situation which makes the assumptions that have been shaping individuals' experience until that moment. The emergency remote teaching imposed by the pandemic Covid-19 resulted in a collective disorienting dilemma for the HEIs at multiple levels [28]. Confronted with this collective disorienting dilemma, faculty, teachers, and students could not apply their prior assumed meaning schemes but engaged in self-examination and critical assessment of familiar meaning perspectives and routines [13, 21].

The connection with the transformative theory offered an interpretative scheme to investigate which professional development activities are suitable to accompany faculty to achieve progressive improvements in time of constraint, disorienting, and emergency remote teaching [4, 9]. It oriented the study towards the analysis of conditions for transformative faculty development, and the recommendations for using what we learned from this collective dilemma to prepare for teaching in unpredictable disruptions [29].

3 Materials and Methods

The purpose of this exploratory study [30, 31] is to analyze how faculty development can be informed by transformative informal learning when facilitated through the faculty communities of practice, which act as a leverage for innovation in organizational processes. Research questions are:

RQ1: How and to what extent has the massive shift to emergency remote teaching changed faculty perspectives on teaching and learning?

RQ2: What are the most promising conditions to support transformative faculty development?

RQ3: How can faculty be accompanied in reconfiguring their professional epistemologies towards new digital based scenarios?

3.1 The Method

Starting from those questions, the Authors developed an exploratory study with colleagues from several subjects belonging to 14 different University departments. 40 faculty from University of Siena took part. Furthermore, 10 faculty and directors of the Centers for Teaching and Learning of foreign universities (USA, Canada, Greece) were interviewed. The research design implied 8 focus-groups and 35 in-depth interviews to gather deep and rich data. Focus group and interviews were videorecorded and transcribed ad verbatim. The interview protocol included (but was not limited to) the following open questions:

- *"What kind of disorienting dilemmas, critical incidents or disrupting moments did you experience during/after the pandemic? Can you provide examples?"*
- *"What supported you in facing these disorienting dilemmas? How?"*
- *"Which challenges did you face during the pandemic?"*
- *"Did your perspectives about teaching and learning change? If yes, how?"*
- *"What was the most important thing you learnt from this experience"?*

Part of the interviews encompassed a format of critical incidents to fully probe and develop a description of participants' experience. The data analysis process was iterative: a thematic content analysis was carried out, using the N-Vivo12 software to support researchers handling the coding, and implied several coding steps in which three researchers worked first independently and then combining the results. Content analysis included coding of responses by constant comparison for embedded categories [31]. The content analysis followed these procedures: a) creation of a preliminary list of more than 100 codes, distributed into 6 clusters; b) themes were predefined after repeated readings of the texts; c) a content log was created, with reflections about discussion content and attempts to group themes as part of the inductive analytical process; and (d) the transcribed texts were coded, producing a final output of 55 textual segments whose analysis reflected the scope of the transcripts and indicated three emerging themes regarding the faculty perspective transformations.

4 Findings and Discussion: How to Encourage Faculty Sense of Belonging

Although this chapter does not provide an algorithm for the success of the faculty development paths, what came out throughout the research is a combination of insightful description, reflections, and pertinent information interwoven, a collective narrative of how to facilitate perspective transformation in faculty development.

4.1 Changes Brought by Emergency Remote Teaching

Transformative learning theory affords an explanation of faculty experiences of fundamental changes in their perspective or frame of references as they engaged in online and blended teaching. Of particular importance to this study, the blended and online teaching worked as a "collective disorienting dilemma", a trigger event that stirred this self-examination on faculty role. The results show significant changes in epistemological perspectives about their professional identity for 30 participants: in the words of one participant "*What changed? My teaching philosophy, my language, my posture with students*" (I.18).

Three themes of perspective transformation experiences emerged from the accounts of the participants: personal change, instrumental learning, and skepticism towards technologically enhanced teaching. In the first two of these, instrumental and technological learning were evidenced, and while both subjective reframing of perspective transformation could be evident, the acquisitions imposed by the online and blended teaching were vividly recounted. However, it is worth to say that only for the major theme of personal change there were indicators and traces of that fact that the shift in the epistemological premises about teaching transformed the teaching practice. For the participants whose stories are coded in the first theme, the challenge of the temporary shift to massive online and blended learning acted as a "trigger" event that broke down the tacit flow of their daily activities. They perceived this forced "stop" of their routines as an invitation to examine their assumptions on teaching and to clarify expectations about themselves and their students. For those faculty, the sense of inadequacy they could feel for a certain period was humbly converted in a cue for professional growth ("*learning new things*") and for being proactive in starting new paths of teaching practices.

For the second theme, the one of instrumental learning, the massive online and blended learning experience brought technical learning but not engaging in evaluating faculty assumptions and beliefs. For the third theme, the skepticism towards technologically enhanced learning, a polarized thinking about a dichotomy between online/in presence teaching still prevailed: "*I am not afraid to come back to the in-presence modality. I didn't want to continue to teach in front of a screen, watching small icons with no eye contact. I hope we will soon return to our classrooms with all students on site*" (I.34). Most part of the faculty, while supporting the importance of implementing technology-based teaching strategies that integrate various digital tools and workspaces, was committed to defend their positions that reflected a reductionist approach, i.e. making use of the Moodle platform only as a repository of educational content and privileging asynchronous courses. This polarized mechanism reinforced the distance between "techno-enthusiastic" and "techno-skepticist", namely those who believe that the emergency remote teaching would elicit rethinking manageable solutions in a perspective of growth, and those who were strongly grounded on their assumptions about teaching in person as the best way to teach effectively. Teaching online required a cognitive and reflective effort on faculty consolidated routines, knowledge, expectations, and beliefs [26]. This led professors to redesign their courses, according to new content management systems, paying more attention to the course preparation: "*Distance and remote connections don't help. Everyone wants to teach more effectively, but often we face barriers and obstacles*" (I. 4). Another participant said: "*Teaching effective distance learning imposes to find out new active technological methodologies, more than just slides and beautiful presentations. This requires creativity to think out of the box*" (I. 14).

The "Zoom Fatigue" [19, 32] represented another challenging barrier: the online (and then blended or hybrid modality) required high resilience and adaptivity, imposing hours and hours of stay in front of the laptop screen, losing the boundaries between work/personal lifetime, and exposing faculty to concrete risks of overwhelming and discomfort feelings. Participants complained about their loneliness in front of the screen. This resulted in another epistemic challenge, because it had impacted on their social professional life and on the informal learning people gain amid their daily practices at work.

One of the faculty members pointed out that *faculty and professors should practice innovative strategies for cultivating participation in online settings only when they feel prepared. There's no such a bad thing in Higher Education like a professor who is not passionate or motivated in what and how he/she teaches. So, first it is important that each professor may develop his/her "toolbox" of learning facilitation strategies, understanding how and when to adopt them in class. There's no one size that fits all, and this assumption also applies when we talk about online teaching during pandemic. As professors, but also educators, we need to recognize the uncertainties and disorientation produced by the Covid-19 pandemic and to carefully evaluate day by day how to creatively personalize our courses to engage students connected remotely* (I.12, 47 years old, professor of molecular biology).

4.2 The 4S Model

Findings suggest that institutions could benefit from the course and initiatives created during the pandemic for updating teaching practices. In addition, from the analysis of participants' responses the research team formalized a model to respond to the new challenges of the post-pandemic university: the 4S model to faculty development, where the 4S is the acronym for Sociocracy, Space, Sustainability and Share dimensions of faculty development. The 4S model organizes into four dimensions the material and immaterial conditions, factors, and contextual elements that moderate and influence the different competencies developed by faculty and the changes in their traditional teaching practices (see Fig. 1). Future research in the field might apply and validate the 4S model to faculty development to enhance faculty self-efficacy and teaching effectiveness.

This model is rooted in the assumption that professors do experience perspective transformation in a variety of formal and informal professional settings [33]. In the 4S, the four elements for facilitating faculty development are formalized along two

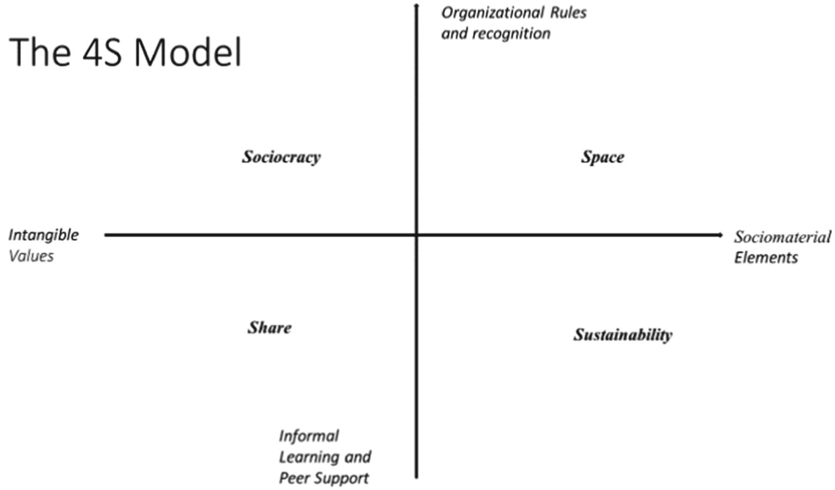

Fig. 1. The 4S Model (Source: personal elaboration of the Corresponding Author)

intersecting axes: on the horizontal axis, there's the continuum that comes from the pole of sociomaterial elements and goes to intangible values; on the vertical axis, there's the continuum that comes from the pole of organizational rules and recognition and goes to the informal learning and peer support dimensions. The following paragraphs describe in detail the four dimensions of the 4-S Model.

Share: Informal Learning and Peer Support mean to have the opportunity to engage with colleagues in open, egalitarian discussions, personal reflections, exploration of different values and beliefs in a non-threatening manner. Several factors can help faculty "stay on course", including intentional facilitation structure, personal curiosity, intrinsic motivation, and – among all – peer support. High levels of peer support play an essential role. The peer support is efficient for many reasons, ensuring timely, positive, and constructive feedback, nurturing relationships, and capacity of listening. Individual and dialogue-based reflection, critical questioning are valuable experiences that need to be integrated into the facilitation of peer support [34].

Through the *Share* dimension, professors can perceive themselves "as comrades in adversity" [24, 35]. This aspect is directly connected to one possible option for cultivating faculty development in HEIs: the cocreation of faculty community of learning [35]. In faculty community of learning, opportunities for expert and novice faculty to learn from each other, explore tentative ideas and unsuccessful experiments can happen [36]. As literature suggested [24, 35], faculty communities of learning are groups of peers, composed by faculty, professors, researchers, and teachers, who meet regularly to deepen some topic related to teaching and learning and/or to share practices and experiences useful to project their professional development [35–37]. They can be cohort-based, when they aggregate members who have the same grade of expertise (newly admitted, in example, or senior professors), or topic-related, when the mission is to explore specific topic of common interests; they can last short-term or long-term; they can follow a formal management system or an informal bottom-up approach; they can be oriented to the personal knowledge and experience sharing or to the instrumental and technical knowledge building. Whatever forms they assume, faculty learning communities gravitate around common purposes, peer support, encouragement, sharing of ideas, willingness to learn from one another, flexibility, situated cultural horizons, and mutual respect [38].

A key component of peer support is also self-compassion, here conceived as the ability to recognize that failure, disappointment, and suffering are all part of professional experience [39]. Self-compassion is a protective factor which can reduce the negative effect of academic stress on both academic performance and wellbeing [39] and enables professors to face failure and adopt healthy and productive learning goals within the classroom. Failure, unsuccess, frictions are coming from previous beliefs and expectations not fitting with current situations and producing discomfort. Peer support offers relational scaffolding structure that stimulates faculty to cope with those frictions and work gradually to change the possible actions they can take. To engage in reflective practice implies to act based on recurring collective critical assessment of faculty feelings, actions, and experiences. The faculty communities of practice can be the inter-relational structure for enacting peer support in academia. In this regard, de Carvalho-Filho, Tio, and Steinert [40] proposed a path of twelve tips for supporting the creation of faculty communities of practice in HEIs.

We also found indications for enhancing peer support among faculty communities of practice also in the words of one participant: *showing respect for others' views, and trusting their motives, which encourages further dialogue and exploring inner assumptions* (I. 31).

Sociocracy: Faculty development can use full-group consensus as a method of decision making especially in faculty communities of practice. Primary reasons for adopting this approach are inclusiveness, sense of belonging, and cultivation of collective intelligence. The interests of all members must be considered, faculty are trusted and encouraged to be self-organizing and supportive of each other [41]. Faculty community of practice, for example, can offer a compensation structure that supports faculty and professors to take responsibility for their own learning and for the success of their effort in changing teaching practices. Accordingly, elective groups of faculties share vision, mission, and aims of the circle, collectively assume, and validate a strategy plan for progress, design their work processes, and clarify role and responsibility of circle members [41]. Sociocratic structures are designed to be dynamic, which is why sociocracy is often referred to as 'dynamic governance' [41, p. 99], with the incorporation of continuous feedback loops. Implementing these dynamic governance models requires scheduling regular meetings, designing the work process in each area of responsibility, and keeping this semi-autonomous and self-organizing framework. "Sociocracy is, above all, about engaging with one another to achieve common aims" [41, p. 207]. It implies contribution to the others, in terms of how faculty members can contribute to the growth of peers, students, institutional actors, organizations, and are committed to the group evolution [28].

Space: Providing a space for learning and discussing perspective and beliefs on their teaching can facilitate faculty to critically reflect on their practices [42, p. 78]. Collaborative spaces embrace co-presenting and co-teaching opportunities. Innovative teaching practices flourish in settings where collegiality is preserved. And resulting from such a spirit of collegiality, faculty members learn valuable ways to support each other. It is necessary to pay attention to the value of teachers' informal learning in relation to innovative teaching in new post-digital environments, which is a relatively low-cost and convenient way to disseminate knowledge and create commitment to active learning methodologies [43].

In providing space, where perspective transformation can happen, faculty seek contextual understanding amid disorienting experiences, and interest in sojourning into further professional growth experiences for themselves, their peers, and their students. The space is theorized as a laboratory of professional "apprenticeship", where faculty can undertake the responsibility for their transformative agentivity in concert with peers, validating, taking risk, experimenting, reflecting, and assessing their approaches on teaching and learning [44].

Sustainability: Faculty involved in our study highlighted that to facilitate the engagement in professional development activities, there ought to be a formal recognition from the university administration of the amount of time, energy and commitment invested. In this regard, one of the concerns expressed in their responses was about the value and possible rewards that could be recognized to their efforts in promoting innovation in teaching among the colleagues of their departments. To operate as a continuing, wellfunctioning, and fully engaged community requires intentional time allocated for collaborative work and institutional legitimization from the top governance of the academic institution. Initially university governance may need to reinforce extrinsic rewards to encourage people to participate in transformational development opportunities. At the beginning, it can work with a top-down process and with an elective group of pioneering faculties more motivated to take part. Then, the "faculty developers" or "change agents" could invite the participation of their colleagues and support their collaborative effort. One means of ensuring that a faculty group can operate as a learning living sociocratic community is through the ongoing use of circle meetings focused on the sharing of knowledge and the creation of new projects [41].

Sustainability in the words of a Director of a Center for Teaching and Learning *means evidence of commitment to initiate and sustain new programs or the ability to redevelop existing programs, with a performance plan with stated goals and indicators of evidence of changes* (I. 43). The literature suggests that organic faculty perspective transformations are not realized through the acquisition of instrumental knowledge, based on transmissive or informative activities, but over time through meaningful engagement in community-based systematic interactions, like the ones produced in communities of practice or communities of learning [33, 45].

5 Relevance to the Field

This exploratory study confirms that transformative learning provides an appropriate and insightful framework for faculty development in HEIs. Original in scope, it aimed to offer an in-depth opportunity to explore how faculty, professors, and researchers who came from diverse backgrounds had found successful way to redesign their courses while dealing with the amounts of dilemmas along the post-pandemic pattern [19, 45]. This research is cast in the framework of the transformative learning theory [21, 46]: looking at professors as professional learners, investigating their experiences of transformative learning and formalizing conditions that support transformations in a model that provides recommendations for faculty development initiatives.

The relevance of this research relies on the formalization of a set of strategies and systemic actions to assist faculty perspective transformations. Future efforts to improve teaching and learning in HEIs should eschew the notion of top-down imposed guidelines or "best practices" universally adopted, and instead meet faculty exactly where they are to codesign peer support programs, communities that are responsive to the realities of the post-pandemic university classrooms [40].

Some key elements are depicted for building a transformative learning framework to faculty development: peer support; facilitation role; sociocratic leadership; intrinsic motivation; mutual recognition of value. Those elements recall similarities and commonalities with the framework for Collegial Faculty Development that Esterhazy, et al. [38] developed from a systematic literature review. Accordingly, individual motivation is furtherly unpacked in the following sub-indicators:

- *objectives*, purposes, and goals that led faculty to group together and engage in communities of practice. In this study, the researchers recognized learning purposes, development goals, proactive achievements that faculty wanted to earn;
- *needs*, learning/training needs, and technical /instrumental needs that faculty cope with the peer support provided in faculty communities of learning. Individual and institutional needs should be linked and aligned, for the benefits of the quality of teaching and student learning;
- *process*, the professional development path that they undergo to increase their capacity of creating effective and captivating lessons and to pursue student success. The process means *how* faculty shared the collective responsibility for changing their perspectives on *what means* student learning and made significant progress in outstanding the teaching practices of their institution. This path embraced the recognition of faculty contribution and acknowledged the importance of safe contexts where learning can flourish.

Conclusions and Implications

The study offered insights relevant for increasing the body of knowledge about innovation in teaching and learning in HEIs, specifically on how to cultivate innovation in teaching and learning in disrupting moments, such as the pandemic one [23]. Nevertheless, the study has main limitations: the exploratory design makes it impossible to identify any interplay between the themes evidenced in the findings. Second, using only qualitative methods to explore perspective transformations and conditions for supporting faculty development simplifies our understanding of innovation in teaching and learning [36]. Third, the sample was a convenience sample from the University of Siena and from a purposeful range of foreign countries universities. In future research, more robust research design should involve mixed-method design and a broader sample of participants from different countries.

Accordingly, one of the future trajectories could be potentially to create an online repertory of promising practices to integrate in digitally enhanced teaching for sustaining learning processes in times of high disruptions and unpredictability. A possibility is here outlined with the informal peer support that the 4-S model shapes. This can bring benefits in a crisis condition for individual participants, such as for the entire organization to adapt to institutional changes for the post-digital scenarios.

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What Technology Enhanced Assessment and Feedback Practices do Italian Academics Declare in Their Syllabi? Analysis and Reflections to Support Academic Development

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Abstract. Nowadays there is a growing attention to teachers' and students' digital competencies in this developed and digital world. Some important theoretical frameworks underline the importance of the development of these new skills, such as DigCompEdu [1] as well as the framework for the development of data literacy for educators [2]. These frameworks are at the bases of our research which is focused on higher education, with particular attention at the university teachers digital and technological competencies. One area that is relatively new and less researched is that of assessment and feedback, namely which use of technology is adopted in evaluative practices.

The contribution aims to investigate, in the Italian context, teachers' use of technology-enhanced assessment and feedback assessment practices throughout the implementation of a syllabi analysis.

Keywords: Technology Enhanced Assessment and Feedback · Digital competencies · Higher Education · Syllabi analysis

1 Theoretical Framework

1.1 Academics' Digital Competences

In higher education, digital competencies are connected to a new emerging professional role that university teachers cover, the role of Digital Scholar, intended as "someone who employs digital, networked and open approaches to demonstrate specialism in a field" [3, 4] so a practitioner who is able to introduce the use of digital technologies and approaches in his/her teaching, assessment and research practices.

Starting from this new university teacher's role, it's important to understand how this topic is connected to the research and how it can determine the basis of this explorative analysis.

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The concept of digital scholarship indicates "a set of practices related to the production and transmission of knowledge through technologies" [5] and the 'digital competence' could also be defined as 'the competence to act in today's digital world' [6].

In light of this, a digital scholar is "someone who employs digital, networked and open approaches to demonstrate specialism in a field" (Scanlon, 2018 p.1; Weller, 2011). The development and growth of a digital scholar "not only refers to linearly growing and developing digital competencies, but also to exploring, hopping around and jumping back and forth, sometimes failing, sometimes succeeding, but always and steadily acquiring new competencies in a more complex, sophisticated way" [6].

Academic development initiatives are therefore called to equip professors with such digital competencies, to use technologies and data in their teaching, learning and assessment practices.

The [1] DigCompEdu (2017), the fundamental basis of the research project, describes the competences of educators and divides them into six main areas and the corresponding 22 sub-competences:

1 Professional engagement
2 Digital resources
3 Teaching and learning
4 Assessment
5 Student empowerment
6 Facilitation of students' digital competence

The focus of the research is on exploring the specific area of assessment to understand how university teachers implement the use of technology in their assessment and feedback practices and to scaffold them in improving these practices. The reason why we decided to focus specifically in the area of assessment are mainly two: this area is relatively under investigated in literature, therefore the research could aim to contribute

Table 1. The European framework for the digital competence of educators – area 4: Assessment [1] (2017)

The European framework for the digital competence of educators - area 4: assessment	
Assessment strategies	To use digital technologies for formative and summative assessment. To enhance the diversity and suitability of assessment formats and approaches
Analysing evidence	To generate, select, critically analyse and interpret digital evidence on learner activity, performance and progress, in order to inform teaching and learning
Feedback and planning	To use digital technologies to provide targeted and timely feedback to learners. To adapt teaching strategies and to provide targeted support, based on the evidence generated by the digital technologies used. To enable learners and parents to understand the evidence provided by digital technologies and use it for decision-making

to filling this gap in literature. Moreover, when it comes to assessment often academics struggle in planning and implementing appropriate assessment and feedback strategies, and technology may offer a significant help to improve and enhance evaluative practices [7] (Table 1).

[2] Raffaghelli (2019) highlights also the importance of these new competences in connection with the topic of data literacy, intended as "the ability to collect, manage, evaluate, and apply data in a critical manner" [8], to be applied in designing and implementing their assessment strategies. In fact, in our era, it becomes crucial to be able to integrate digital competences with specific competencies related to the best use possible of the data produced during the teaching, learning and assessment process.

[2] Raffaghelli (2019) identifies three main skills that educators should develop in designing and implementing their assessment strategies (Table 2):

Table 2. Reference framework for the development of data literacy for educators [2] (2019)

ASSESSMENT	Assessment strategies	To integrate the data produced throughout the learning process for formative and summative assessment purposes
	Analysing evidence	To generate, select, critically analyse and interpret data as evidence of learner activity, performance and progress, in order to inform teaching and learning
	Feedback and planning	To use the data produced throughout the learning process to provide targeted and timely feedback to learners. To adapt teaching strategies and to provide targeted support based on the evidence generated by the digital technologies used. To enable learners and other stakeholders to understand the data as a form of evidence provided by digital technologies

All these contributions in literature gave us the input to reflect about the new professionalism of the contemporary university teachers and then related approaches to scaffold academic development in this particular age, so the 'age of evidence' that put the attention on how these programmes concretely impact student learning [9], which is the major aim of higher education institutions. The analysis presented below, in fact, aims at exploring current practices of technology-enhanced assessment and feedback in order to tailor professional development pathways that can help university teachers developing digital competences.

1.2 Technology-Enhanced Assessment and Feedback

In order to deeply focus the research theme and to contextualize the relation between university teachers competencies and digital technologies, we investigated in literature the concept of Technology Enhanced Assessment (TEA), intended by [10] Devedzic and

Devedzic (2019) as a general term that includes different methods, by which technology can be used to support the management and implementation of assessment in educational settings; it enables teachers to conduct assessment with an innovative approach. TEA supports the implementation of assessment methods that scaffold the development of particular students' competencies, such as analysis, evaluation, and creation of new knowledge; TEA methods and tools also provide rich learning experience, improve learning efficiency, and increase knowledge retention [10, 11]. Examples of TEA methods and tools can include self-assessment, peer assessment, e-portfolios, e-checklists, e-rubrics, concept maps, journal entries, digital storytelling, collaborative development projects using Social Web tools, and presentations and discussions using e-communication tools [10].

The literature highlights the growing interest in TEA practices in higher education: TEA is seen as a set of strategies that enables peer assessment, self-assessment and can support assessment challenges such as distance and flexible learning and large student enrolments [12, 13] while also developing the ability to generate "constructive, timely and 'easy to understand' feedback" [14, 15].

Undoubtedly, feedback plays a key role in improving student learning [16, 17]. However, the impact of feedback varies according to different sources of feedback and context [18]. In this regard, in the last 10 years, the teacher-driven conception of feedback has been replaced by a socio-constructivist conception, according to which feedback is considered a dialogical process. In this view, students actively co-construct the feedback, e.g. through collaboration with their peers. Students' active participation is a key factor for feedback to be effective and thus improve their learning [19–21].

However, while designing and implementing effective feedback processes is not an easy task, as it requires numerous specific pedagogical skills on the part of teachers, the online environment proves to be a tool that can facilitate this process [7, 22, 23].

In this sense, another important issue related to the introduction of technology into assessment and feedback practices is brought to light by [12]. They highlight the fact that new technological strategies and tools could, in fact, stimulate:

- the implementation of multiple types of assessment to foster learner choice;
- the development of new strategies to introduce summative assessment;
- the achievement of important skills such as peer interaction and collaboration; and
- the use of data analysis to inform assessment practices.

In this historical period, it seems evident that the introduction of digital devices and technologies in general in educational contexts can implement meaningful opportunities to create environments characterised by variety, fluidity, dialogue and sharing [24], customisable and diversifiable, that can introduce crucial components like motivation and engagement in order to sustain effective learning.

Indeed, the pandemic period highlighted the high versatility of e-learning platforms, which offer multiple possibilities and tools that can be used to foster feedback [25]. In this sense, digital environments maximise the opportunity to create learning contexts enriched by different sources of comparison, capable of generating effective, motivating and learning-enhancing feedback processes [7, 26].

The present research focuses on strategies to support academics' technology enhanced assessment and feedback practices, highlighting the opportunities for learning offered by semi-automated assessment systems [27], intended as systems characterized by the automatisation of the feedback process through the use of specific digital platforms and tools. In order to tailor academic development programs, it becomes crucial to understand the state-of-art of current TEA practices in Italy: this was achieved by a large syllabi analysis described in the next paragraph.

2 Methods

2.1 Research Aims and Questions

The research intends to investigate, in a national context, university teachers' use of technology-enhanced assessment and feedback practices using a syllabi analysis process, with the final aim to create and validate a training model to scaffold their professional development as Digital Scholars.

The two main research questions are the following:

1. What technology-enhanced practices do university teachers implement in their assessment processes?
2. Are semi-automated feedback practices included in Italian academic assessment processes?

The research interprets the syllabus as the official document that concerns faculty's teaching practice, thus considering it as an essential tool for understanding the assessment and feedback approaches adopted by university teachers in the national context.

2.2 Sampling Methodology

The reference population, used for the sample creation, is the university teaching staff of the Italian state and non-state universities. In detail, the 60.158 professors holding the following positions were taken into consideration: full professors; associate professors; researchers; full-time researchers; extraordinary professors. From this number of subjects, we considered and analysed the syllabi corresponding to 3008 university Italian teachers.

For this first part of the research, here presented, we decided to take into account the university teachers belonging to the Mega Italian State University: the decision was motivated by the belief that the context of Mega-Universities could offer a broad overview of the Italian context. Therefore, 1145 university teachers were included in this part of research; they represented the 5% of the entire population (n = 22968 lecturers from the Italian state-owned mega universities).

Since there is no state-level repository containing all the syllabi belonging to all active lecturers and their related courses, it was decided to start by creating this sample identifying academics themselves, and then to randomly select one syllabus per lecturer.

Then, each syllabus was downloaded, and a document dedicated for each Mega University investigated was created; after the creation of the documents, a content analysis using the software Atlas.ti 22 was carried out.

2.3 Analysis Procedure

The syllabi selected were explored through a content analysis shared process: in fact, two independent judges led the analysis, throughout the constant negotiation of the meanings. The analysis procedure was developed first collaboratively, in order to share common actions and practices and apply the shared meanings in a consistent way. This first part was concluded with the identification and calculation of the interrater reliability, intended as a statistical method that provides "a way of quantifying the degree of agreement between two or more coders who make independent ratings about the features of a set of subjects. And then independently" [28]. In order to calculate the ICC and the related interrater reliability for the ratings, we first applied an Anova analysis Two-Factor Without Replication. The interpretation was conducted following to the model of [29] Koo & Li (2016); in fact, they suggest that:

- values less than 0.5 are indicative of poor reliability,
- values between 0.5 and 0.75 indicate moderate reliability
- values between 0.75 and 0.9 indicate good reliability, and
- values greater than 0.9 indicate excellent reliability [29, 30].

After this collaborative phase, the independent judges continued the analysis in an independent manner; at the end of the entire process, the judges revised together the sample and related results derived by the use of the shared codes and meanings (Fig. 1).

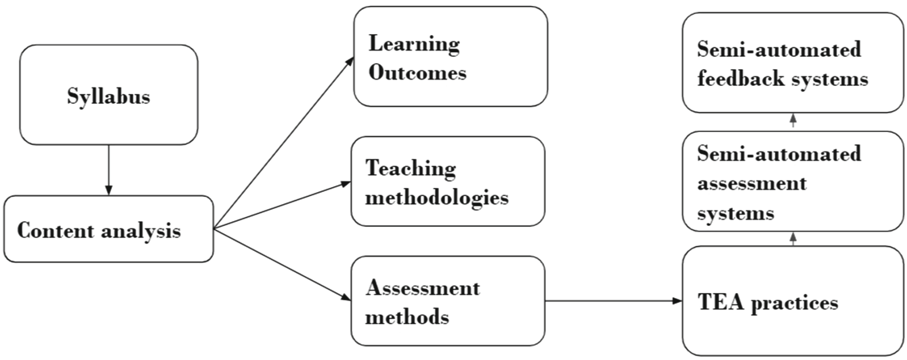

Fig. 1. Syllabi's analysis procedure

It is important to underline that this specific research is part of a bigger project that aims to analyse the whole structure of the syllabi collected, starting from the main part of the syllabus itself, so the sections dedicated to the learning outcomes of the course, the connected teaching methodologies and then the assessment methods. From this last section, we developed the focus of the research, so we put the focus on Technology enhanced Assessment and Feedback practices, continuing the inquiry in terms of semi-automated assessment systems' use and, in particular, semi-automated feedback system" implementation.

The analysis of the content was developed through the use of a coding rubric, created using the literature [27, 31–33]), in order to better focus categories and codes and then carried out a concrete investigation of the research themes (Table 3).

Table 3. Coding rubric created with the use of the literature

Online assessment & tools	• Computer Based Assessment (CBA) • Learning Management System (LMS)
Semi-automated marking and feedback system	• Self-peer assessment online tools • Semi-automated Feedback system and tools • Semi-automated Marking system and tools

This rubric is the result of deeply reflections and literature research: at the beginning, the exploration revealed very specific terms related to the field of technology enhanced assessment, proposing important differences between the type of systems and the different tools used to introduce process of enhancement in assessment and feedback processes through the implementation of digital technologies.

Due to the analysis' context and its heterogeneity in syllabi structure and compilation, we decided to create two main categories, so "online assessment and tools" and "semi-automated marking and feedback system"; in these two categories, we introduce specific codes that could have allowed us to analyse the content of the syllabi more easily. This strategy was introduced in order to identify terms that could encompass a wide range of meanings, with the aim of maximising results and thus having a coding rubric adaptable to the different types of documents drafting in the university context of reference.

3 Results

The syllabi, referring to each university teacher, were randomly downloaded from the official website of the related University (Fig. 2).

In the total number of the sample, 149 syllabi weren't available on the website and then they could not be taken into consideration for the analysis.

After a preliminary analysis, 164 syllabi were excluded due to lack of information concerning the examined part of interest; in fact, the judges couldn't totally investigate the whole content of the syllabi excluded because one or more sections didn't include enough data that would allow them to be effectively codified.

Finally, from the initial sample composed by 1145 university teachers and related syllabi, the judges were able to analyse 832.

During the analysis, to better sustain the process and the related results, the calculation of the interrater reliability was carried out; the index corresponded at 0.96 so, thanks to the interpretation model of [29] Koo & Li (2016), we can assume that the according between the two independent judges during the content analysis was excellent (greater than 0.9).

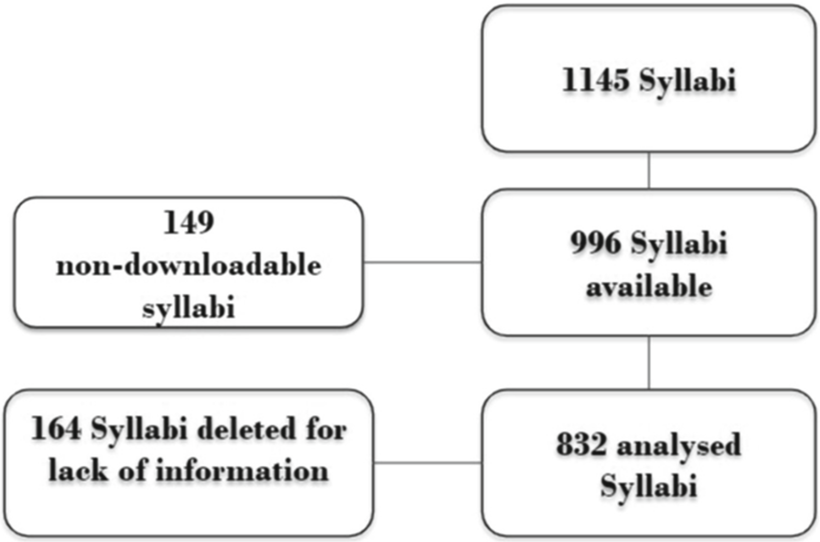

Fig. 2. Syllabi's selection procedure

The results show that, within the selected sample, only 3,4% of the syllabi included the presence of Technology Enhanced Assessment and Feedback practices.

Out of this 3,4%, 6,9% mention the use of semi-automated assessment systems.

Here some examples of quotations identified during the coding process (Table 4):

Table 4. Examples of quotations from syllabi content analysis

Semi-automated feedback e marking systems	Online assessment & tools
9:121 "Access to the examination through online quizzes with closed questions"	1:534 "A quiz to be taken on the Moodle platform based on a mix of multiple-choice questions, exercises and graphical analysis"
10:462 "During the course, anonymous questionnaires will be administered via web applications to monitor in real time the level of comprehension of the content and if necessary to carry out remodelling"	1:569 "written test administered via the Moodle platform with exercises relating to the various topics covered in the course of the lectures"
10:635 "An online quiz tests the students' understanding of the pre-lecture material"	2:607 "Final written computer-based test (closed questions, open questions and data analysis)"

Starting from the two principal research questions "1. What technology-enhanced practices do university teachers implement in their assessment processes?" and "2. Are semi-automated feedback practices included in Italian academic assessment processes?", we can see that the quotations underline that the use of semi-automated assessment systems could be connected to specific teaching moments; in fact, it seems that these kinds of systems were used in a formative way as a tool for accompany learning process, especially used to scaffold the students' preparation for the final exam.

In general, the preliminary analysis shows that there is a lack of use of assessment or feedback practices implemented through the use of technology among the university Italian syllabi. The analysis is still ongoing for the whole sample of all Italian universities, but it already appears that only a minority of teachers declare to use technology-enhanced assessment practices.

4 Discussion

As [6] Van Petegem and colleagues said (2021), the nature of the digital world will inevitably have an impact in terms of professional learning and in the way in which university teachers choose to manage their learning opportunities in terms of continuous professional development and to innovate their teaching practices.

The authors in fact underline that the redesign process of these practices could be implemented at two level:

- macro level: redesign the whole module or unit with the integration of digital technologies where appropriate, critically consider the different learning and assessment activities and how they align with the course learning outcomes.
- micro level: redesign the practices introducing one approach or a small set of tools to get started, with the consequent identification of sections of work where such an approach would be educationally appropriate [6].

This future view of continuous professional development in the digital era is crucial for the research in order to collect data and to continue to explore this field and create effective strategies that can support Italian professors in their teaching, learning and assessment processes enhanced through the use of technology.

In contrast to the literature, the results of the syllabi analysis highlight a little use of assessment and feedback practices supported by the use of technology (3.4%). It seems clear that only a minority of academic make effective use of technology-enhanced assessment, both for summative and for formative practices.

With particular attention to the topic of semi-automated feedback system, the literature [34–36] investigates and highlights the effectiveness and the greater formative value of the automatic feedback provided by the technological system: timely feedback involves students in a continue monitoring processes of their learning, supporting their skills' development.resulting. From the academics' point of view, the use of automatic feedback would stimuli them, according to [35] Tang, Rich and Wang (2012), to acquire a role of supporters and facilitators of the formative processes. The results report a very little presence of use of these systems and it will be important to understand why and what kind of actions and research will be useful to implement in this direction.

Despite the pandemic and the remote emergency teaching, it seems that academics still need training and guidance to integrate technologies in formative and summative assessment and even more in feedback practices.

However, we are aware that the data emerged could be influenced by a research limitation: in the syllabus, university teachers might not directly declare the use of technology in the area dedicated to assessment and feedback practice, but instead they may use some of these tools in class and in the final exams.

In fact, each University has the possibility to manage the structure and the guidelines related to the syllabus creation: it means that the syllabus framework can be personalised by the institutions and it represents the possibility to have different information in the document. This produces a heterogeneous scenario of this fundamental formative document in which different institutional formats may invite (or not) teachers to include an explicit mention to Technology Enhanced Assessment and Feedback practices.

To fill this gap, we hope in the future for a shared syllabus model at a national level, with includes specific mention to the technology use in teaching and learning, including assessment and feedback practices, as a part of the new directions connected to the digital progress in the University field. A learner-centred syllabus represents a clear learning agreement between teacher and students and should therefor include information on summative and formative assessment, assessment criteria and type of use and delivery of the assessment itself, including methods enhanced by the use of technology [37].

To conclude, the importance of support for the development of new digital competencies in university teachers emerges from the research data as crucial in the area of assessment. These results of the research will inform the next phases of the research and the consequent creation of faculty development processes aimed at fostering the development of new skills for university lecturers to become digital scholars.

5 Conclusions and Future Perspectives

As the literature points out, the use of feedback in the technological environment can be realised as a continuous and automatic device. The integration of technology into assessment processes seems to represent a stimulus for assessment innovation, a way to introduce more deeply the learner-centred approach of teaching and learning [15]. In these terms, a systematic literature review was developed by [33] Tonelli, Grion and Serbati (2019): the research highlights that effectiveness of the integration of technology and assessment is evident in both summative and formative assessment processes, and this introduction seems to bring students closer to assessment.

From the research results it emerges the necessity to guide university teachers in the integration of technology in assessment and feedback processes in their teaching, with particular attention to the Introduction of Specific Formative Activities.

As mentioned before, the research is part of a larger project that aims to investigate a representative sample that will include all Italian state and non-state universities, composed by 3008 university teachers and connected syllabi. The larger sample will allow us to confirm or disconfirm results found so far with a smaller sample.

Furthermore, the research group will then carry out a further investigation using questionnaires and interviews involving a smaller sample of academics, in order to identify Technology Enhanced Assessment and Feedback good practices. In fact, we still believe that the syllabus, being the formal document for teaching design and for communication with students, represents the best source of information to have a picture of the national state-of-art of TEA practices. However, to address the research limitation above mentioned, questionnaires and interviews will allow a deeper comprehension of the current assessment and feedback practices and tools enhanced by the use of technology.

This exploratory study aims inform the process, already guided by the literature, to create models and actions to support the professional development of university teachers with a particular focus on new skills and practices related to the use of technology, to support a gradual process of innovation of assessment in teaching practice.

The topic of training and coaching of university teachers in the implementation and us of technologies in assessment processes it is crucial: in fact, only after the construction of a structured and considered path they could better understand, experiment and reflect on new integrated tools and their related impact on learning outcomes and in general in teaching, learning and assessment processes [33, 38, 39].

To conclude, it seems fundamental to support research lines related to this particular theme in order to disseminate practices and to sustain a culture of digital innovation in education.

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Academic Development Strategies to Support Teaching and Learning Processes Integrated with Technologies: Lessons Learnt at University of Trento

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Abstract. This article presents the reflections developed by the members of the Scientific Committee (SC) of the FormID, Teaching and Learning Centre at the University of Trento, on the Centre's directions and perspectives, with specific reference to the role played by learning technologies. The reflections also address problems and opportunities experienced by the SC members and, above all, the identification of strategies to support academics' professional development. The research addressed two questions: how is it possible to establish a new recognised identity for the Centre and how to orient its actions to maximise the benefits of technologies in teaching and learning practices? The research adopted a collaborative ethnographic approach: the main results emerged from the narratives are discussed and interpreted using the eight P's framework [1]: purpose, people, place, practices, profile, politics, professional development and publication.

Keywords: Teaching and Learning Centre · E-learning · Professional Development · Collaborative ethnography

1 Introduction and Theoretical Framework

When the pandemic arrived in 2020, the urgent need to support academics in the challenge of designing effective teaching and learning processes became very clear. The urgency was certainly to effectively integrate technology in the classroom and to promote quality online learning, but there was also the necessity to develop a supportive teaching community, recognising the efforts of teachers and students to jointly create the best possible learning opportunities in a stimulating environment.

In 2018 the University of Trento promoted a strategic called "FormID", Centre of Competence for Teacher Training and Teaching Innovation, which today has become the Teaching Learning Centre of the University. The Centre promoted a series of training actions aimed at promoting quality teaching and supporting meaningful, participative and personalised learning. The professors reacted very positively to these opportunities by participating in large numbers, so the governance of the University realised that there was a real need for them to learn teaching and learning strategies and then the Centre

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decided to plan more structured approaches to support their professional development [2, 3]. Thus, on the one hand, training initiatives had already been successfully launched to foster the quality of teaching, and, on the other hand, the emergency urged the need of a massive and widespread adoption of new teaching technologies in education, forcing academics to deal with predominantly unfamiliar teaching methods.

As [4] Kotter (1996) recalls, in order to really scaffold the improvement in teaching, it is indeed necessary that the organisation truly wants to invest on it and also that the people perceive the need of such a change.

As the literature points put at national and international level, several universities, also looking at the studies conducted on the effects of academic development paths, have already increased their offers and services dedicated to the teaching staff, introducing structures called Teaching and Learning Centres (TLC), with the primary aim of promoting the professional development of academics [5, 6].

The creation of a TLC represents the main action to sustain a process of faculty development, in order to promote at the same time professors' teaching competences and, consequently, the ability of the academic institution to positively impact on the territory, by offering a robust preparation of the graduates, future professionals who belong to it [7].

Scholars and experts in the field of academic development emphasise how the birth and development of a TLC, in addition to organisational choices, first require broad decisions, related to the definition of goals and priorities to be addressed, and resources to be identified [8]. The definition of the vision, mission and values of a TLC requires in-depth group work among founding and managing members, aimed at agreeing on what is the final goal to be achieved, what are the inspiring principles, and what are the methods through which these goals are to be achieved.

In order to share these elements among the members of the FormID Scientific Committee, led by the Vice-Rector for Education, a research was conducted to initiate a shared reflection on its future trajectories. The aim was to create an ongoing participative process that could lead to the creation of a structured and centralised Centre for Teaching and Learning with a clear vision and a shared mission. The members of the Scientific Committee, therefore, designed a shared pathway, a sort of journey, which could give the opportunity to become aware of the development phases of the TLC, reflecting on the most important topics to be addressed. This research also aims to consolidate the working team, to create empowerment, motivation and to develop a shared vision of change [4]. The focus of the research presented here is specifically on the trajectories identified to support academics in improving their technology-enhanced teaching and learning practices.

The research adopted a collaborative ethnography [9]. Members of the FormID Scientific Committee (SC) engaged in a dialogic reflection that drove awareness of processes and achievements, a better understanding of FormID practices, the identification of new perspectives, and the planning for sustainable organisational change that could benefits and maximises the opportunities offered by technologies.

The research aims to take a few steps forward to answer two questions: how is it possible to establish a new recognised identity for the Centre and how to orient its actions to maximise the benefits of technologies in teaching and learning practices?

2 Methods

The research used collaborative ethnography [9, 10]. Ethnography is a research method that involves individuals in cultural analysis and interpretation [11]. The process of exploration and questioning helps the individuals to position themselves within their own story and culture, enabling them to broaden their understanding of their own values in relation to others. Ethnography can be considered collaborative by definition, however, making such collaboration a goal for ethnographic production means making the participants active in the research process. It means circulating the researcher's interpretations, making them subject of comments and feedback by participants themselves [9]. The choice of a qualitative methodology was aimed at helping SC members to explicate tacit thoughts and make critical reflections on the topics under investigation.

An ethnographic interview was then carried out with FormID SC members. The questions were inspired by the framework proposed by [1] Le-May Sheffield (2022), which identifies eight P's, through which analyse the design and development of a TLC. The proposed areas of interest are the following: *purpose, people, place, practices, profile, politics, professional development and publication.*

Particular attention was given to the topic of technologies in teaching. For this purpose, in addition to the SC members, it seemed necessary to also interview two members of the University OnLine Centre (DOL), who collaborate with FormID. The researcher collected the individual narratives of the eight members of the SC and of the two DOL members, who shared their history within FormID, their critical events and their reflections on the eight proposed areas.

The interviews were recorded and transcribed. The responses of the subjects involved were then analysed with content analysis using Atlas.ti software [12]. The coding process was carried out by the researcher using the framework of the 8 P's and shared with the members of the Scientific Committee; the identification of the codes could in fact become material for subsequent collective reflections with the SC on the themes that emerged from the analysis.

In this contribution, the data collected is presented by showing the identified categories and related codes followed by some examples of quotations. Given the small number of participants, it was decided not to calculate percentages connected to each code.

3 Results

The topic of technologies in education was investigated from the eight 'P' framework proposed by [1] Le-May Sheffield (2022). Regarding each point of analysis, we will present what is the current situation and what the reflection of the members of the Scientific Committee has identified as working trajectories and objectives to be achieved in the near future.

In relation to the first P, '**purpose**', the participants aim to stimulate an overall qualification of the academics in order to scaffold their teaching and technological competences to maximise the students' learning experience. For many members it becomes important to create a 'culture of teaching' in the university, considering both face-to-face, online and blended activities.

In the interviews a dual function of technologies emerges: on the one hand, they represent one fundamental content in the academic development initiatives in order to equip professor with technology-enhanced teaching competences; on the other hand, technologies are also a means of communication and training and thus it is important to offer a learning environment where they can access synchronous and asynchronous online training (Table 1).

Table 1. Information Communication Technologies (ICT) and teacher training

Categories	Subcodes	Quotations
ICT_Teacher Training_Content	– teacher training on ICT_pedagogical thinking – teacher training on ICT -digital literacy – teacher training_sharing CdP	*"I think that technology should be mastered very well by teachers and so technology training should be done" (9:2)* *"…that is, the person should be educated not in the tool, but in the thinking behind it" (3:4)* *"It's my way of interacting. So I use technologies a lot; and so in a community of practice maybe I also talk about these things" (8:35)*
ICT_Teacher Training_Tool	– teacher training _facilitates experiences – teacher training_enables diversification of methods – teacher training_along with presence	*"I see an important role of the technology especially from the very point of view of an ease of access, that is, ease of using technologies to facilitate access to experiences, practices, materials, and so the idea of the repository seems to me to be very useful or other tools" (7:1)*

Focusing on technology as '*content*', the various members of the SC emphasised the need for a 'pedagogical approach to the use of technology', focusing on the design of a well-balanced integration of technology in teaching and learning practices rather than on the technical aspect [13]. The interviewees agreed that if appropriately integrated into teaching practices, through teaching strategies and collaborative learning, technologies represent an added value for all those involved in the educational process.

Furthermore, participants emphasised that Communities of Practice [14], already established at University of Trento, can also become a way in which the potential of technology can be discovered, starting from the bottom, by sharing the experiences of individual professors in order to reflect on the advantages and difficulties in their use.

With respect to the use of technologies as a *tool* for teacher training, it emerges from the interviews that technologies facilitate access to experiences, practices and materials, thus enhancing training. They also make it possible to diversify the ways in which professors can be trained, alternating between presence and distance (blended). The technologies, for example, enable the uploading of multimedia materials such as videos, blogs, literature, glossaries, that can be consulted by academics for self-directed learning.

As far as '**practices'** are concerned, the training offered by the FormID during the academic year 2021/2022 was devoted both new teachers and to all academics: a three-day semi residential workshop for new faculty and five workshops on teaching and learning topics were designed and offered: student voice approach, interactive teaching for large classes, and assessment for learning. In addition, two meetings were dedicated to the design of teaching and learning with technology.

Moreover, among the first activities already implemented by FormID, as mentioned above, five Communities of Practice were established as important environments to identify the experiences and digital devices used by academic in online/blended teaching. In this regard, the Scientific Committee has launched a training needs analysis by interviewing departmental teaching delegates and by administering a questionnaire to all academics), to investigate teaching practices and digital resources adopted, in order to be able to better tailor academic development initiatives.

According to the interviewees, there is a need to organise both general workshops (that can be applied to all disciplines) as well as discipline-specific training courses, along with the need and therefore the objective of also setting up online resources for their self-training. In fact, some professors emphasise the need to have short tutorials available in order to be supported in learning specific technological devices. To support self-directed learning, a further action initiated concerns the creation of a new TLC website that will include new resources for synchronous and asynchronous use.

In relation to the function performed by technologies, respondents recognise their value as a support function for teaching (Table 2).

Table 2. ICT as institutional support

Categories	Subcodes	Quotations
ICT_educational support	– increases teaching strategies – function_to improve the quality of teaching – opportunities_ blended_flipped – attention_presence prevails – opportunities_asynchronous_lesson recovery – support for student exchange – blended advantages_distance management – tools for collaborative work – development of students' soft skills	*"The functioning of Moodle, the functioning of the forum, the discussions, but the same Mentimeter, Wooclap, all these tools allow to give immediate feedback, to have contact with students in a much more direct way, and that is fundamental" (9:4)* *"I see it as more necessary than ever to continue training in the integration of technologies, but not as technologies per se, but as the fact that instructional design today can no longer be separated, I would not even separate instructional training, instructional design from the use of technologies anymore" (4:5)* *"In my opinion, we need to learn technology better, we know how to use it little, but the sense must be to improve our teaching and not absolutely a substitute" (9:5)* *"I use technology, but actually I am a classroom animal. So I like it when it comes to help, not when it replaces interaction" (8:24)*

Technologies, therefore, primarily support face-to-face teaching, but they also allow various difficulties to be managed (i.e. recordings of lectures can be very useful for students, asynchronous online activities can be very engaging and effective, collaborative environments can be set up, etc.)

For the '**people**' topic, FormID's activities are managed by the SC, that also collaborates with the administrative staff and with the Online Centre - DOL for technological training. A further necessary element for integrating technologies into the teaching and learning processes that emerged from the interviews is the need to create synergy between professionals and institutional centres, under the supervision of the TLC (Table 3). In particular, it would be important to strengthen the collaboration with the staff of the DOL Centre to better integrate technological and instructional design skills into the TLC's offerings [15].

Table 3. ICT Development Needs

Categories	Subcodes	Quotations
ICT_ Devlopment_Needs	– DOL_ synergy among the various centres – Synergy among centers – middle management needs – DOL_escalation post emergency – DOL_support figures – DOL_rapidity software purchases – DOL_recognition to faculty – DOL_needs scientific direction	*"So, technology integration I see it through; 1) synergies to be put in place DOL and Formid; 2) with dedicated actions and resources and people who can have time to help everyone to integrate technologies in the way he/she thinks is appropriate with respect to his/her discipline, content" (4:12)* *"Of course, that's why we need academic developers, because they can put all the pieces together with the different technologies" (1:1)* *"Integrating response systems during classes and using various Moodle tools" (4:16)* *"if you saw what the potential of technologies could be, not to replace face-to-face teaching, but to reinforce it, to enhance it, that is, you should ride this moment in a structured way"(7:4)*

One aspect highlighted by both the members of the SC and the DOL members is the need to improve the training with further actions to support and accompany teachers in the actual application of technologies within their teaching, with the help of academic developers and instructional designers.

The SC members added a further necessary element to support the teaching culture:

- To do research on disciplinary teaching and the impact of using technology-enhanced learning environments;
- to organise activities to monitor the results, with the aim of constantly improving the process.

These actions are important to verify whether and how the innovation is working and to gather evidence of the results achieved. Interviewees emphasised that university teachers need to be supported by experts who design and follow the research together with them. This process, known as SoTL (Scholarship of Teaching and Learning), makes it possible to enhance teaching innovation also in the wider academic community.

As far as '**politics**' is concerned, the Centre is undergoing a major transformation, moving from a project-based Centre to a Service for the University, a structure that does not simply provide training, but supports academics in their continuous professional development process. This is already indicated in the University Strategic Plan (2022–2027).

To do this, it is clear that TLC must be placed at the centre of the permanent institutional strategy to support teaching excellence, with strong integration with the other university's service centres.

In terms of '**profile**', the centre has so far promoted several academic development initiatives. To consolidate this goal, in addition to workshops, seminars and communities of practice, other activities will be enhanced such as co-design of teaching innovation with academics, support in SoTL implementation as well as the production of online resources. A call for teaching innovation projects is also planned, in which academics will plan their innovative actions and receive support for its implementation. These actions are also designed and introduced to identify the most promising teaching practices and disseminate them.

In terms of ICT resources, the above mentioned synergy with DOL services, with instructional designers and educational developers and the collaboration with students are encouraged (Table 4).

Table 4. ICT Development Resources

Categories	Subcodes	Quotations
ICT development Resources	– Synergy with DOL_instructional designer – educational developer – DOL_resources_internal expertise – DOL_Cognitive Science support – DOL_network membership e-learning centers – DOL_student involvement	*"So DOL where there are colleagues who are instructional designers, so they really follow the design aspects, of instructional design of individual courses or even pathways of study. You can then have initiatives to involve students, outside experts, and to enhance best practices in the University" (4:10)* *"DOL makes its expertise available with a series of workshops that can be online, in-person with very small numbers of faculty or on a continuous cycle, then with open workshops" (6:57)*

Regarding the ‘**place**’, FormID can currently benefit from spaces in the Teaching and Student Services Unit and in the School of Innovation, with the aim to expand such space, with a specific focus on enhancing the connection with the other university facilities. This future action will be crucial in order to structure learning environments that benefit from the implementation of digital technologies that support active and interactive training and effective technological progress at institutional level.

At the end of the points investigated, in order to foster the ‘**professional development and publication’** of the Centre’s staff, the SC members intend to: increase participation in conferences, research on academic development actions, impact assessment and research on teaching with technologies. The aim is to consolidate a working team with complementary competences, which can provide support to university teachers in teaching design and in monitoring actions.

4 Conclusions and Future Directions

Starting from the research question on how to establish a new recognised identity for the Centre and how to orient its actions to maximise the benefits of technologies in teaching and learning practices, we can say that what emerged from the interviews gives us some useful prompts.

Regarding the aspect of the TLC identity, the members of the SC are unanimous in identifying academic development initiatives towards teaching excellence as the fundamental mission. The centre should progressively play the role of coordinating also other service centres at university level.

As for the second research question, the SC members urged the need to understand the pedagogical underpinnings that drive technology integration, in accordance with research in the field [16–19]; in fact, the literature highlights that the use of technologies (synchronous and asynchronous) in the classroom and the use of tools are not directly linked to positive or negative outcomes [20]. To ensure positive results, it is necessary for teachers to understand technologies and integrate them into a coherent teaching and learning design. Thanks to the rich pedagogical reflection of recent decades, it is therefore important to identify models and strategies to make the best use of media in learning and teaching [21].

This requires academics to become ‘designers’, capable of making appropriate choices to respond to the educational demands of today’s society [22].

A real process of innovation in teaching, learning and assessment practices does not only require individual teachers to change their methodologies and actions in the classroom, but also the development of a teaching and assessment culture that truly places the student learning at the centre [23]. The active role of the student in the development of his or her own learning constitutes the key element of the paradigm shift that changes the focus from teaching practices and methodologies to learning processes [24] and underpins the culture of excellence in teaching.

Trying to summarise what was described in the results of the research, we identify the two priority areas of action: on the one hand what the members of the SC called “teaching culture” and on the other hand the ways of fostering the development of technologies in education (Table 5):

Table 5. TLC trajectories emerged from the research

Trajectory	Actions
Culture of teaching excellence	– training academics in teaching design, in order to move from transmissive practices to active and participative practices integrated with technologies; – proposing multiple ways of delivering academic development initiatives (presence, distance, blended, short and long courses, workshops, seminars); – identifying, experimenting and monitoring innovative teaching methods, technologies and materials, useful to improve the quality and effectiveness of teaching by promoting projects/calls to encourage experimentation in teaching innovation; – collecting and valuing good practices implemented by academics, so that they can be disseminated; – monitoring and evaluating educational innovation experiences, developing quantitative and qualitative analysis tools that gather the level of effectiveness of the interventions implemented; – preparing online resources for academics' self-training (technology tutorials, webinars, articles, best practices, etc.); – setting up a system for evaluating the impact of academic development courses; – scaffolding within the TLC the pedagogical and technological competences of the working team; – organise conferences, seminars, courses for the greater dissemination of the culture of quality, teaching innovation and faculty development

(*continued*)

Table 5. (*continued*)

Trajectory	Actions
Training and development in the use of technology in education	– offering workshops to integrate technology in teaching and learning; – creating synergy with the OnLine Teaching Centre to increase instructional design skills and strengthen the technological infrastructure and know-how in digital content production; – sharing experiences in the use of technologies among the communities of practice already operating in the University; – investigating the digital tools used in the university and providing specific training on these to disseminate and strengthen their use; – providing diversified training that is responsive to the specific needs of the disciplines; – preparing tutorials for training on specific digital resources; – scaffolding the role of academic developers with expertise in pedagogical and technological aspects, who support the teachers in the implementation of teaching innovations and in research on disciplinary didactics and the use of technologies; – involving students as collaborators in supporting teachers in the use of technology for teaching

The data collected and presented in this contribution highlight a new need felt by the members of the FormID Scientific Committee, namely to also pay attention to the development of a culture of teaching excellence, led by FormID. The lines of action that emerged from the ethnographic study are several and indicate possible identity trajectories of FormID, which envisage the Centre's staff engaged in intensive work on the implementation of academic development actions for individuals, groups, and institutions in a collaborative and community environment.

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A Phenomenological Study About the Effect of Covid-19 Pandemic on the Use of Teaching Resources in Mathematics

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Abstract. In this contribution, we discuss phenomenological research related to a pilot study carried out by the Consortium of the MaTeK Horizon 2020 project during the 2020–21 academic year. The research aims to analyse the effects of the Covid-19 pandemic on the use of teaching resources in mathematics in five countries. A questionnaire made of seven questions was administered to a data sample made of teachers of all grades. The answers coming from the questionnaire were quantitatively and qualitatively analysed. Closed-ended questions were analysed by using a clustering methodology called k-means. Open-ended questions were qualitatively analysed. The results show that almost all the teachers are aware of the impact of the Covid-19 pandemic on education. However, their perception of how the pandemic situation changed the use of educational resources mostly appears linked to cultural factors, age, teaching experiences and school grades of the teachers.

Keywords: Phenomenological study · Teaching resources in mathematics · Covid-19 pandemic · Cluster analysis

1 Introduction

If we study the history of societies, we can find several pandemic events such as smallpox, cholera, plague, and, more recently SARS [1, 2]. Each one of these pandemic events affected human life in many aspects from health to the economic sphere [3]. Education is one of these aspects. In 2020–21, the SARS-CoV-2 pandemic (Covid-19) has had a massive impact on Education. Students from different countries have been affected by

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school and university closures. Italy was the first Western country to suffer a coronavirus emergency. On March 4, 2020, the Italian Prime Minister announced a strict lockdown and the immediate closure of all schools and universities to contain the spread of the virus.

This phenomenon then extended to other countries as well all over the world. In response to school closures, UNESCO recommended the use of distance learning programs and opened educational applications and platforms that schools and teachers can use to reach learners remotely and limit the disruption of Education. These proposed "solutions" involved all levels of Education [4, 5]. According to [6] Covid-19 has shown different everyday situations and different related emerging problems around the world. The problems with connectivity and stability of the internet connections were only minor parts of them. A new environment implied looking for using new pedagogical and didactical perspectives in revising competencies needed for the further life of the pupils (what, how and why the need to learn) and those who should be adopted by teachers [7, 8]).

In 2020 and 2021 several researchers investigated teaching practice and their response to the crisis [7, 8]. Steed and Leech [9], discussed the US teachers' difficulties in personal interactions with students and their inadequate resources. Hu et al. [10], painting the Hong Kong Covid-19 teaching scenario, provided evidence of barriers including difficulty engaging students in online activities and highlighted inadequate support from several parents for learning activities. Nikolopoulou [11] highlighted teachers' negative feelings in particular, at the beginning of online education in Greece. Brunetto et al. [12] proposed a new teaching model for describing and analysing a new teaching system in Covid-19 time. Several Researchers in [5, 11–13] put in evidence as the pandemic was for many teachers and students the opportunity to re-examine their teaching/learning also concerning the use of curricular resources.

The types of resources used by teachers fall into different categories. Pepin, Gueudet and Trouche [14] distinguish 1) curriculum resources, 2) social resources, and 3) cognitive resources. Curriculum resources are "developed and used by teachers and students in their interaction with mathematics in/for teaching and learning, inside and outside the classroom" [14, p. 172–73]. They are further categorized as a) text resources (e.g. textbooks, syllabi, websites), b) digital curriculum resources (e.g. e-textbooks, educational platforms), and other material resources (e.g. calculators, digital instructional technology) [14].

The study of resources and mathematics teachers' interaction/work with those resources has become a prominent field of research (e.g., [14]). Very few of these works deal with the effect of the Covid-19 pandemic on resources used by teachers.

That was one of the reasons we decided to focus on this phenomenon. This research is one thread of the different researches conducted under the Horizon 2020 MaTeK (Mathematics Teacher Knowledge) project (2021–2023) in which five universities from as many countries are involved: Comenius University in Bratislava, Slovakia; Charles University, Czech Republic; University in Palermo, Italy; NTNU, Norway, and METU, Turkey. Our consortium focuses on enhancing the design capacity of pre-service mathematics teachers. Preparation of future mathematics teachers is specialized and includes mathematical and pedagogical content knowledge as well as reflecting this knowledge in practice [15]. The process includes the use of resources, and the ability to judge and design own materials when making and enacting a lesson plan [16]. Teacher knowledge is the prerequisite of the education enterprise, and student knowledge development is its objective. Therefore, it is essential to understand what kinds of knowledge mathematics teachers develop, and how they use their expertise in teaching to help students to develop deep knowledge of mathematics [16]. Since that pre-service teachers are often not adequately prepared to cultivate opportunities for students to engage with reasoning and proof [17, 18] we are focusing on reasoning and proving skills. These skills also form an important strand of mathematical proficiency [19, 20]. The main framework used to study this research subject is referred on Stacey and Vincent's theory [21].

In this contribution, we refer to the study that the Consortium did about this theme and in particular the work that was done about the study of the Covid-19 pandemic effects on the use of resources by all grade teachers. In the following paragraphs, we discuss the methodology used for this research (an open-ended questionnaire was designed ad hoc) and some remarks about the results obtained from a pilot study carried out at the end of the 2020–21 academic year.

2 Methodology

2.1 Design

A quantitative and qualitative research design was used to determine by an open-ended questionnaire the repercussions of the Covid-19 pandemic on the use of resources by teachers. This phenomenological research aims to describe how teachers from several different school institutions of all five MaTeK countries express and make sense of their shared experiences with the complex phenomenon/scenario that they are living in pre/during and post Covid-19 times. In this context, we focused on teachers' feedback about their experiences of meaningful activities, compatible with Covid-19 restrictions on the use of teaching resources [14, 22].

2.2 Participants and Questionnaire

The research involved 110 voluntary teachers from several different school institutions of all five MaTeK countries. The involved teachers – mainly females (83%) – had 3–25 years of work experience in teaching Mathematics, as main taught subjects. All participants were ensured anonymity.

The questionnaire was designed by a strong collaboration between all five MaTeK partners and was online administered. It is made up of twenty-three items aimed to focus on some key aspects in studying teachers use of resources in mathematics, in several topics such as refreshing or improving teachers' personal knowledge in mathematics, inspiration or ideas for teaching mathematics, preparing assessments, finding materials to be used with their students in class. Six more question were dedicated to particularly analyse teacher's conceptions about Reasoning, Proving and the related of teaching resources [23–25]. The last part of the questionnaire was dedicated to collect demographic data such as age, experience, etc.

In this contribution we only refer to a subset of questions in the questionnaire. In particular, we analysed the answers given to questions related to demographic data such as age, gender, highest degree of education, taught subjects (other than mathematics) and school grades of the teachers and the two questions reported below.

Q1- *To what extent did the Covid-19 pandemic situation change the way you used educational resources compared to how you use them now?*

Q7- Please, *describe how the Covid-19 pandemic situation has changed the way you used educational resources compared to how you use them now.*

Q1 is a closed-ended questions and the answers were collected by using Likert scales. Q7 is an open-ended question and the answers were qualitatively analysed. All other demographic questions are closed-ended questions. All closed-ended questions were quantitatively analysed by using *k-means* clustering method.

3 Data Analysis and Results

Data coming from closed-ended questions in the questionnaire were quantitatively analysed by using Cluster Analysis (ClA) method [26]. ClA aims at grouping the elements of a set in different non-overlapping clusters, that can be analysed to deduct their distinctive characteristics and to point out similarities and differences between them. Particularly, in this study, we used a non-hierarchical clustering method, called k-means [27], as it allows researchers to individuate clusters that are also easily represented in Cartesian graphical form.

The answers were coded by using a binary scheme. Each teacher was identified by an array composed of components 1 and 0, resuming the answers given by him/her in the questionnaire. For the sake of simplicity here we refer to the use of a two-level coding, where 1 means that a given answer was used and 0 means that it was not used by a student.

Table 1. An example of data matrix. The *N* teachers and the *M* answers are denoted as T_1, T_2,…,T_N., and as A_1, A_2,…,A_M, respectively.

Answers	Teachers			
	T_1	T_2	…	T_N
A_1	0	0	…	0
A_2	1	0	…	1
A_3	1	…	…	…
A_4	0	…	…	…
A_5	1	…	…	…
…	0	…	…	…
A_M	0	1	…	0

For example, let us say that teacher T_1 used answers A_2, A_3 and A_5 to respond to the questionnaire questions. Therefore, column T_1 in Table 1 contains the binary digit 1 in the three cells corresponding to these answers, while all the other cells will be filled with 0.

All data elaborations were performed by using custom code written in *C* language and MATLAB by one of the authors.

In order to find the number q of clusters that best partitions our sample, the mean value of the Silhouette function S [28] was calculated for different numbers of clusters. We found that the best partition of our sample was achieved by choosing $q = 4$ clusters ($<s(4)> = 0.69$). The obtained mean value is higher than 0.6, indicating that reasonable cluster structures have been found [29].

Once the appropriate partition of sample has been found, each cluster was characterized. To do this we took into account the answers most frequently given by the teachers for each cluster, which according to Springuel et al. [30] can be called the "prominent" answers.

Figure 1 shows the solution obtained by applying the k-means method. It shows the four clusters that best partition our data set and the related centroids. Each point in this Cartesian plane represents a teacher and is placed in a given cluster because it is more similar to the teachers in the same cluster than the ones in the other clusters of Fig. 1 [31, 32].

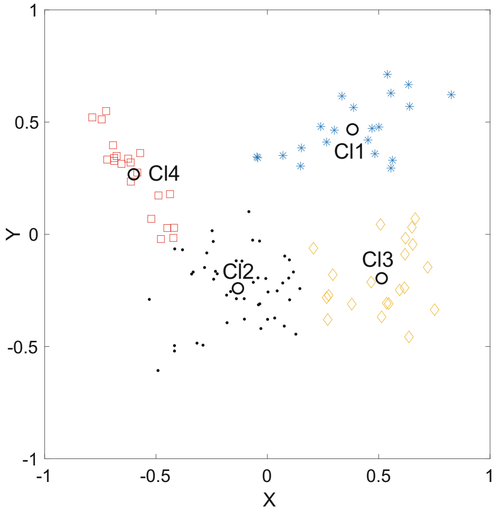

Fig. 1. K-means graph. Each point in this Cartesian plane represents a student. Points labelled Cl1, Cl2, Cl3 and Cl4 are the centroids.

To the values reported on the axes X and Y it is not assigned a specific meaning. Only the distances between each couple of teachers are relevant and represent the dissimilarity between each couple of teachers with respect the answers given to the questionnaire.

It is worth noting that some points may be placed at the boundaries of different clusters. The k-means method classifies these teachers in a specific cluster and associates them the behaviour obtained by the most frequent answers in the cluster. However, those points may actually represent teachers that exhibit mixed behaviours, involving characteristics of the neighbouring clusters. In particular, this happens for some points in Cl2 cluster and some other in Cl3 and Cl4 clusters.

The k-means method should, therefore, be understood as giving global-type information, and must not be considered as a way to study the characteristics of each element in the data sample in detail that could be obtained referring to a qualitative analysis. We are still working in the direction of a qualitative analysis to further detail our results.

4 Discussion

In this section, we discuss the results obtained by the clustering analysis further detailed by a qualitative analysis of the answers related to question Q7.

Table 1 summarizes the answers most frequently given by the teachers in each cluster (i.e. the components of the related centroids) [32, 33]. It follows the coding used in the Appendix. The number of students in the clusters is also shown.

Table 2. The answers most frequently used by the teachers in the questionnaire and the number of teachers for each cluster. The answers are shown by means of the coding reported in the Appendix.

Cluster	Cl1	Cl2	Cl3	C14
Most frequently given answers	Q1.d, Q2.a, Q3.f-g-h, Q4.b, Q5.d, Q6.b	Q1.d, Q2.a, Q3.d-e, Q4.b, Q5.b, Q6.d-e	Q1.b, Q2.a, Q3.g-h-i, Q4.c, Q5.b, Q6.d-c	Q1.c-d, Q2.a, Q3.m, Q4.c, Q5.b, Q6.b
Number of teachers	21	47	21	21

The k-means analysis allowed us to find four clusters that are represented by the four centroids, which describe the prevalent behaviour of the teachers in the clusters (Table 2).

Upon examination, teachers in cluster Cl1 appear to be young Turkish teachers (age 25–29) from 6th, 7th and in part 8th grades, almost female. These 21 teachers in the Cl1 cluster show a clear behaviour that is significantly different from the other teachers in the sample. They appear to be aware (fourth level on 6 of a Likert scale) that the Covid-19 pandemic explicitly asked teachers for a change in the use of resources. In replying to Q7, they also highlighted that this change requires a perspective change in teaching, as discussed by Pepin et al. [14]. They clearly state that Covid-19 strongly influenced them, changing their use of resources. They strongly refer to a “shift” from text resources (e.g. textbooks, syllabi, websites), to digital curriculum resources (e.g. e-textbooks, educational platforms), and other material resources (e.g. calculators, digital instructional technology).

The centroid strategies of Cl2, show different teachers’ behaviours in Q1, with more detail in the answers to question Q7. Cl2 cluster represents the biggest group of teachers (47 teachers) not culturally homogeneous in which it is possible to find teachers from Norway, the Czech Republic and, albeit to a small extent, Slovakia. Cl2 appears to represent “old experienced” teachers (age 40–59), almost from 4th, and 5th grades, almost female. They appear to be aware (at the same level as Cl1) of the effect of the Covid-19 pandemic on the use of resources. In this case, they also reply to the questionnaire highlighting the significance of the changing process regarding the use of teaching resources. In replying to the Q7 question, they underlined in what ways the Covid-19 pandemic changed the way they used resources. In some cases, they refer to a new use of digital curriculum resources (e.g. e-textbooks, educational platforms) or other material resources as digital instructional technology for teaching (e.g. for preparing lessons, and assessments). However, some other teachers appear still anchored to the traditional logic of resource use. Some teachers refer to classical text resources (e.g. textbooks, syllabi) as one of the most useful resources for teaching.

The clusters represented by centroid Cl3 and Cl4 have the same numerosity as Cl1. (21 teachers for each one).

Cl3 is composed of “mixed experienced” teachers (age 30–49), almost from 7th, 8th and 9th grades, almost female. Cl3 cluster, as the Cl2 one represents a group of teachers not culturally homogeneous in which it is possible to find teachers from Italy and in small part from Slovakia.

The most given answers of Cl3, show a strongly different teacher behaviour on the Q1, detailed by the qualitative analysis of the Q7 question. These teachers appear aware of the effect of the Covid-19 pandemic on their teaching on level 2 of the Likert scale. They reply to Q1 highlighting a not significant change of resources in the pre and post Covid-19 times. Analysing their reply to the Q7 question, they appear more “conservative” than all the other colleagues from different countries in Cl1 and Cl2. It appears very clear that for them (especially for the Italian teachers) the classical printed version of textbooks and all the classical text resources remain the most useful resource for teaching even after Covid-19.

Very few teachers in Cl3 refer in the questionnaire to a strong change in the daily use of digital curriculum resources or digital instructional technology for teaching. This result screeches (and surprised us) with the data related to their degree of education that is higher than the teachers in the Cl1 and Cl2 clusters.

The cluster Cl4 is made of 20 young Czech teachers (age 25–29) from the last grade (13th), almost female. Cl4 teachers appear moderately aware of the effect of the Covid-19 pandemic on their use of resources. Analysing Q7 answers it is possible to de-tailed this data. Some Czech teachers refer to a new use of digital curriculum resources or digital instructional technology for teaching, useful for them in preparing lessons or helping students in a classroom or, finally for the student’s assessments. Some other teachers appear still anchored (even if less than the Cl2 and Cl3 teachers) to classical text resources (e.g. textbooks, syllabi) as useful resource for teaching.

By also analysing the data related to Q7, the most used resources before Covid-19 were textbooks and discussions with colleagues. After Covid-19 time, some Czech teachers (some similar behaviour was found in cluster Cl2 about Slovak teachers) frequently use digital resources (such as GeoGebra, WolframAlpha, etc.) and professional online platforms for teachers. Other typical/classical resources remained the same after the Covid-19 situation.

5 Conclusion

Some researchers (e.g., [34]) highlight an increase in the use of technology and new software environments during the Covid-19 pandemic. In this contribution, we discuss a pilot study carried out during the 2020–21 academic year by the Consortium of the MaTeK Horizon 2020 project concerning the effects of the Covid-19 pandemic on the use of teaching resources in mathematics. Quantitative and qualitative methods were used to analyse the answers given to a questionnaire by a set of teachers. We only refer to a subset of questions in the questionnaire designed in the context of the MaTeK Horizon 2020 project. In particular, we analysed the answers related to the demographic questions such as age, gender, teaching experience, the highest degree of education, taught subjects (other than mathematics) at School and the two questions reported below.

Q1- *To what extent did the Covid-19 pandemic situation change the way you used educational resources compared to how you use them now?*

Q7- Please, *describe how the Covid-19 pandemic situation has changed the way you used educational resources compared to how you use them now.*

Q1 is a closed-ended question and the answers were collected by using Likert scales. Q7 is an open-ended question and the answers were analysed using a qualitative analysis. All other demographic questions are closed-ended questions. All closed-ended questions were quantitatively analysed by using K-means clustering.

Young teachers appear to be more open to changing their teaching than the "older" ones. We observed that young Check and Turkish teachers are aware that the Covid-19 pandemic explicitly asked them for a change in the use of resources and that this change also requires a perspective change in teaching. In many cases in Q7 answers, they strongly refer to a "shift" from text resources (e.g., textbooks, syllabi, websites) to digital curriculum resources (e.g., e-textbooks, educational platforms) and other kinds of resources (e.g. calculators, digital instructional technology). The "Older" teachers in our sample are aware of the impact of the Covid-19 pandemic on student learning. However, their use of teaching resources was not always strongly influenced by that. Italian and Slovak teachers in Q7 answers highlighted such a kind of behaviour much more than the teachers from other countries.

We think relevant some results regarding teachers with a high degree of education (Master, mainly Italians and Slovaks) independent of their age. They are aware of the impact of the Covid-19 pandemic on student learning, but still do not feel significant daily use of digital curriculum resources or digital instructional technology for teaching [35], sticking with the use of old-fashioned resources, like textbooks.

Turkish teachers are all grouped in a single cluster, showing a remarkable cultural homogeneity concerning the use of teaching resources. The same happens for almost all Czech teachers in Cl4. Italian teachers exhibit similar behaviour, being included in a single cluster, which also contains some Slovak teachers. The remaining part of Slovak teachers is in another cluster, together with Norwegian and a few Czech ones.

It is worth noting that Czech teachers exhibit mixed behaviours concerning the use of resources in teaching due to the Covid-19 pandemic. They recognize the importance of updating the resources, due to the pandemic emergency. In some cases, replying to Q7 they appear still anchored to the traditional use of resources. These results deserve more deepening and will be an object of further study, also by the Consortium.

Some more conclusions can be inferred using a closer analysis of the single answers given by the teachers to the questionnaire Q7 question. A preliminary result of such a kind of analysis seems to highlight that the majority of teachers feel the need to change their use of teaching resources. However, they find hard to do it in their everyday teaching coming from 4th and 5th grades. These results also deserve deepening and will be the object of further analysis, mainly by using further qualitative methods of data analysis.

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Appendix

Q1 – To what extent did the covid-19 situation change how you used to use resources and how you use them now?

a- 1 – Not at all
b- 2
c- 3
d- 4
e- 5
f- 6 – To a great deal
g- No answer

Q2 – What is your gender?

a- Female
b- Male
c- Prefer not to say

Q3 – Please indicate the grade level(s) you are teaching mathematics this year (2021–22) – You may select more than one option:

a- 1st Grade
b- 2nd Grade
c- 3rd Grade
d- 4th Grade
e- 5th Grade
f- 6th Grade
g- 7th Grade
h- 8th Grade
i- 9th Grade
j- 10th Grade
k- 11th Grade

l- 12th Grade
m- 13th Grade

Q4 – What is the highest degree of education you have completed?

a- High School
b- Bachelors
c- Masters
d- Ph.D.
e- No answer

Q5 – What subjects other than mathematics do you teach?

a- Science related subjects (chemistry, biology, physics)
b- Social Studies related subjects (examples)
c- Arts or humanities (examples)
d- No answer

Q6 – What is your age?

a- Under 25
b- 25–29
c- 30–39
d- 40–49
e- 50–59
f- 60+

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Training Faculty Developers in Hybrid Mediation: Organisational-Didactic Changes in the TLC Uniba

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Abstract. The need to redefine the teaching-learning processes from a teacher-centred to a student-centred vision envisages the implementation of organisational and didactic changes already envisaged by the reform inspired by the Bologna process. In order to facilitate the actions of change and innovation in higher education, universities usually target one or more figures acting as manager of Faculty Development actions and programs: these are the faculty developers, "agents of change" and promoters of the improvement of didactics within the departments. In 2021/2022, the University of Bari structured a curricular training model for faculty developers, intentionally designed to encourage the creation of interdisciplinary networks at the departmental level. The aim is to activate, within the organisation chart of the Uniba Teaching and Learning Centre, a community able to facilitate an analysis of its practices and to formulate proposals for innovation to fulfill the system level in the University. The curricular model and the mixed-methods research-training protocol structured to evaluate the impact of training actions in hybrid teaching are described.

Keywords: Hybrid Mediation · Faculty Developers · Teaching and Learning Centre

1 Changes in Higher Education: Qualification of Teaching and Hybrid Learning Environments

The Recommendations of the Ministers of the European Higher Education Area [1] highlighted how university teaching qualification processes are related to a student-centered vision of learning, the continuous improvement of teaching practices and the ability of universities to support improvement of teaching-learning processes.

The need to redefine the teaching-learning processes from a teacher-centered to a student-centered vision [2] envisages the implementation of organisational and didactic changes already envisaged by the reform inspired by the Bologna process (1999) and subsequently highlighted by European policy recommendations aimed at increasing

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teachers' pedagogical training and the development of skills not only of a transpositional-disciplinary and research nature, but also functional to the implementation of appropriate teaching, design and content evaluation methodologies [3]. Teachers, through a more active, experiential and reflective teaching action, should respond to the learning needs of an increasingly heterogeneous student body and promote problem solving, team working and metacognition skills, skills that are increasingly in demand in the world of work [4]. Investing in the improvement of teaching and learning practices through training activities promoted by universities to assist lecturers in their roles is a fundamental aspect of the development of the university institution, organisation and people [5].

The implementation of organisational-didactic changes, already envisaged by the Bologna reform [6] and aimed at promoting students' skills, appeared even more necessary due to the Covid-19 emergency. It has been a push towards an organisational rethinking of universities and greater flexibility and hybridization of learning environments [7–9].

The growing use of digital tools in the university context, in fact, has led to changes both on an organizational and didactic level and in research, resulting in an improvement in teaching and learning processes thanks to more flexible and accessible virtual spaces [10–12]. Furthermore, technologies allow for more personalized and accessible forms of learning, making it possible to reach a growing number of students of different age groups [13]. However, these changes often have resistance on the teaching level of educational practice since the most suitable technological tools for the construction of a virtual space for the delivery of contents and the management of interaction with students are called to evaluate the degree [14], and thus having to combine their professional, pedagogical, and relational skills with technological ones. This requires the teacher to adapt his teaching strategies and the ability to act in different contexts, in presence and at a distance [12]; by universities, new training approaches to promote sophisticated not only disciplinary and/or pedagogical, but also technological-logical [15]. The pandemic crisis, then, determined the maximum breaking point with traditional university teaching, requiring teachers to accept a process of technology acceptance [16], to redefine their own didactic actions and to integrate the tools in the didactic mediation. Such transformations can be an investment in teacher training, a high-quality professional development, leading to an advancement in the field of digital scholarship, which supports the professionalism of teachers and for the development of teaching skills aimed at improving the student learning [12, 17].

The professional development of the teacher, in fact, is considered a relevant aspect in the change of teaching practices and in the way in which universities conceive teaching/learning also in relation to technologies: it is therefore considered a development process not only individual, but organizational.

This has led universities to structure interventions in favor of hybrid teaching and the development of teaching skills through Faculty Development actions [18]. These are part of the Teaching Learning Centers (TLCs): university structures, now widespread internationally [19, 20], which aim at the educational success of students through support for the professional development of teaching staff and innovation in teaching [18] and diversified actions adapted on the basis of the specificities of the context, including, for example: the creation/implementation of communities of practice, the promotion of recognition and reward services and systems, curricular improvement and/or teaching research services; accompanying interventions (counselling, mentoring, peer observation, community development, self-training resources, etc.); the involvement of stakeholders at various levels; appropriate management and leadership; full faculty involvement; administrative support and economic and structural resources [21–23].

2 The Faculty Developer as a Change Agent in University Teaching

In order to facilitate the actions of change and innovation in higher education, universities usually target one or more figures acting as manager of Faculty Development actions and programs [4]: these are the faculty developers, "agents of change" [24] and promoters of the improvement of didactics within the departments [13, 25].

The faculty developers are not only an intra-departmental but also an interdepartmental and interinstitutional link figure: they allow the creation of a network for the professional and organizational development of each department, favoring the construction of interdisciplinary connections and communities of practice [4]. As stated by Lueddeke in 1997, faculty developers can "help convert future possibilities into practical realities" by influencing each department's motivation for innovative teaching practices by assuming a bottom-up logic in order to achieve an improvement in the quality of education. Educational offer, of the entire University.

The faculty developer's task is to build and manage the culture of development and the construction of the professional identity of university teaching, guiding, and supporting teachers in the transformation process. To design targeted and more effective transformative interventions, the faculty developer must be able to understand and address concerns and resistances that hinder change. A change that can be of the first order when referring to the ways of teaching and in this case the effort to implement new techniques and strategies promoted by the work of the faculty developer usually does not produce resistance in the teaching staff; second order, on the other hand, 'touches' the personal identity of the university teacher, is more transformative, and involves people at multiple levels (researchers, associates, ordinary) and in multiple roles. This requires a profound rethinking of didactic practices, evokes the need for even unpleasant comparisons with the practices of others, and can lead to questioning the modus operandi of individuals [26, 27]. By virtue of these aspects, the faculty developers must have interpersonal skills and knowledge of adult development in order to understand the relationship between personal, professional and institutional change (this is a slow process that can meet resistance); pedagogical, didactic and building curricula knowledge in order to facilitate the adoption by teachers of non-traditional approaches; ability to identify teachers' educational and professional needs and gather information on teaching and learning practices used to implement educational reforms [13].

They act within the Teacher and Learning Centers (TLC) and are involved in processes of negotiation, construction and tuning of knowledge, skills, and identity with the organisational context [28]; their training activities should be oriented to facilitate an adaptive and situated use of knowledge, supporting the reflective capacity on practice.

The University of Bari has started on the basis of the needs analysis emerging from the PRODID research project [29, 30] the structuring of pilot training paths for the professional development of university teachers in UNIBA Teaching Learning Laboratory (TLL), first Teaching Learning Centre located at the Department of Education Sciences, Psychology, Communication.

In 2021/2022, the University of Bari structured a curricular training model for faculty developers, intentionally designed to encourage the creation of interdisciplinary networks at the departmental level. The aim is to activate, within the organisation chart of the Uniba TLC, a community able to facilitate an analysis of its practices [31] and to formulate proposals for innovation to fulfill the system level in the University.

2.1 What Hybrid Mediation for Faculty Developers?

The Uniba curricular model is based on the recursion between theory and practice and on the representation of the teacher's knowledge as 'professional', practical [32] it takes its origin from the already tested model of the Faculty of Engineering (LTH) of the University of Lund in Sweden which considers pedagogical competence in teaching [33] as a spiral process (according to the model inspired by the learning cycle of Kolb) [34] in which theoretical knowledge (Theory: knowledge of teaching and learning), pedagogical practice (Student Learning-Teaching) and teaching skills (Teaching Skills: Teaching Design; Teaching and Learning Observation) interact.

The model features a "drop down" menu [35] and provides for different target groups: at an institutional level (macro), the Quality Presidium; at the training level of the trainers (meso), the departmental representatives – faculty developers; at the level of groups of teachers (micro), the communities of practice.

The model – based on adult learning [36] and professional learning methodologies – hinges on:

– the development of active learning and the use of differentiated mediators [37] called "artefacts" and which include communicative tools, such as stories, images, case studies, videos, simulations, portfolios, research-actions, lesson-studies; tools to facilitate the generation of practices such as storytelling, analysis of practices, observation or documentation of experience, educational technologies; tools that facilitate relational dynamics and the negotiation of experiences);
– hybrid mediation, considering technologies no longer simple tools for the transmission of knowledge, but redefined teaching as mediated action to high hybridization potential [8] in an adaptive and flexible learning perspective [11]. The mediating role between content and learners is played by the e-teacher and takes the form of integrated and diversified tasks: searching, comparing with other sources, critically selecting and making information available (access); mediating it on the basis of content meanings (assessing and managing), knowledge structure (integrating and creating) and learner characteristics (communicating), making sense of the information available through digital technologies [38], thus through processes of mediatisation [39] and sophisticated mediation [32, 40]. In hybrid mediation, the e-teacher reprocesses, represents, adapts and produces new forms of knowledge that differ from the initial information available, expanding the students' knowledge possibilities: such mediation cannot take

place only through generic pedagogical and technological strategies – such as those recalled by the TPACK model [38, 41, 42] – but requires new spaces of adaptation and remodelling [43] from a structural and organisational point of view of disciplinary content to the specific needs of students [38, 44, 45];

- co-construction and epistemological dialectics between knowledge to overcome the obstacle of curricular compartmentalization: the training modules designed in the curricular model have therefore been constructed on the basis of interdisciplinary teams [46] and a constant dialectic (and subject of video research) between the group of researchers of general didactics and different disciplinary target groups, who can cooperate in course design and peer learning practices [47];
- building communities of learning: to cope with rapid changes in higher education and professional development, educators need new ways to work together, collaborate and exchange information in a community that is active and connected [48]. The creation of learning communities favors greater socialization between teachers, facilitates and develops a sense of belonging to the faculty and involvement of the faculty avoiding the risk of isolation and thus improving teaching processes and organizational skills [48, 49]. The purpose of the involvement of the faculty developers is to activate a community able to foster an analysis and reflection of and on its own practices in action [31] and to formulate – through the mediation of middle figures management, such as the faculty developers [7, 35] – proposals for the innovation and qualification, recognition and enhancement of university teaching to be implemented at system level in the University of Bari, through sharing with academic governance organs.

The format to be adopted for the training provides not only moments of formal activities through workshops, seminars, but also informal ones based on processes of collaboration and sharing of practices and experiences, to create communities of practice and promote the ability to problem solving, team working and metacognition [50, 51]. These training moments will be delivered through a hybrid mode that includes both face-to-face and remote sessions using synchronous tools for participating in webinars and asynchronous tools such as the use of web-forums to facilitate discussion and activate reflex processes and self-reflective on practices [50, 52].

The choice of the hybrid course delivery method is based on some elements that emerged from the literature [48, 50, 52, 53] concerning the fact that the use of a platform and therefore of digital tools can foster greater flexibility and autonomy of trainees in accessing sources and in the use of materials and knowledge, available in any place and at any time, facilitating forms of self-directed learning and greater moments of reflection and self-evaluation. The use of technologies in professional development also offers greater opportunities for teachers to relate and connect with other colleagues to share mutual interests and experiences [48].

22 departmental representatives (one for each department) were selected as faculty developers willing to engage in the hybrid mediation training course, to implement the knowledge acquired in teaching practice and to support the training of new hires and expert professionals, with different skills profiles. The course includes the involvement of experts at national and international level, in co-teaching. Also, thanks to specific adaptations of the Moodle platform, tools for re-elaborating the experience will be used to support critical reflection on the practice (Table 1).

Table 1. Articulation of the training course

Activity/Module	Target
Mod. 1 – The professional profile of the university teacher • Teaching profession • Skills framework • Teaching Learning Center organization • Support figures for university teaching • SOTL – the skills of the university teacher • *Best practices*	• Understanding the competences of the university teacher • Understand the organization and operation of the Teaching Learning Centers • Becoming aware of the virtuous relationship between research and teaching and adopting research into teaching
Mod. 2 – Designing the didactic intervention • Syllabus, SUA form, outgoing student profile • The design of the syllabus • *Best practices*	• Understanding and knowing how to use the syllabus as a tool for teaching • Knowing how to design an effective syllabus
Mod. 3 – Learning and teaching for didactic mediation • Didactic mediation • Service Learning • Learning and teaching: student centered environments and dynamics • *Best practices*	• Promote the development of knowledge and skills with a solidarity service to the community • Knowing how to use student centered approaches and models for learning
Mod. 4 – Technologies and didactic innovation • Distance and blended teaching • Design learning environments • *Best practices*	• Knowing and knowing how to choose appropriate methodologies for learning • Innovate teaching by knowing how to design and use digital tools • Knowing how to design digital learning environments
Mod. 5 – Assessment in learning • New approaches to evaluation • Summative and formative evaluation • Skills assessment • *Best practices*	• Knowing how to consciously adopt assessment for/of learning approaches • Knowing how to prepare and use a competency assessment rubric
Mod. 6 – Community work • Adult education • Building communities of practice • Working in teams and in professional communities • *Best practices*	• Acquire skills for professional action in a social context

A survey which involved the administration of qualitative-quantitative data collection tools was designed: a multiple and open-ended survey and probing interview questions. The survey is part of a mixed-methods research-training protocol (Fig. 1) structured to evaluate the impact of training actions in hybrid teaching, the learning actually achieved, the possible repercussions on teaching practice and the point of view of the participants in the training, starting from the explanation of their motivations, expectations, previous knowledge, training needs.

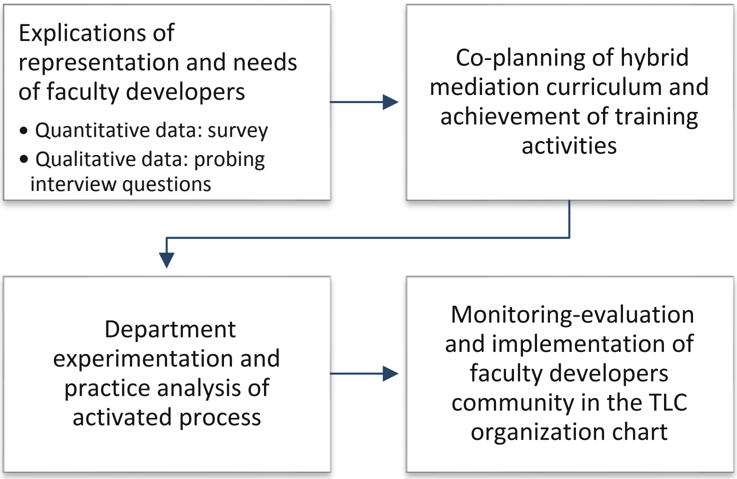

Fig. 1. Research-training process on hybrid mediation to faculty developers

Tools for reflexive revision of the experience will be used, also thanks to specific adaptations of the Moodle platform, to support critical reflection on practice and highlight the most impactful, useful, and transferable aspects in teaching and organisation, at Athenaeum level. The use of reflective and self-assessment tools to promote the professional development of lecturers at the academic level has already been tried and tested: Let us recall, for example, the experience of the University of Helsinki with the 'HowUTeach' project [54–56] which focused on the dimensions that substantiate teachers' pedagogical competence and, in particular, on approaches to teaching (learning-centered, content-centered, non-reflective teaching, organised teaching); on work environment experiences (interest and relevance, support from colleagues, autonomy, integration of teaching and research); well-being (stress – general and teaching-related – burnout, self-efficacy, anxiety, recovery from work-related stress, self-compassion).

The curricular model for the training of faculty developers within the Uniba TLC also envisages course monitoring and impact assessment actions; documentation actions, such as the drafting of an annual report on training to be returned to the departmental communities; communication actions, such as short video spots and podcasts to be publicized on the university website. More specifically, among the evaluation actions, a qualitative-quantitative and mixed-methods protocol has been structured to assess the impact of training actions on didactics which, in addition to customer satisfaction actions, investigates the learning achieved, the possible repercussions on teaching practice and the point of view of the training participants, starting from the explication of their motivations, expectations, previous knowledge and training needs. The faculty developers will offer useful feedback on the usefulness and quality of the proposed methods, as well as on the actions to be implemented at a systemic level in the university.

3 Conclusion

The attempt, as suggested by the literature on the topic, is to implement a participatory and multilevel research approach capable of taking into account the plurality and complexity of the effects of training evaluated starting from the recognition of the point of view of the stakeholders, personally involved in the implementation of innovation and university quality [57–62].

Change in university education is always both individual and organizational, involving systems and cultures underlying professional contexts [63]. As argued by Kathryn A. Sutherland [64], it is necessary to broaden the sphere of support actions, which do not only concern the creation of favorable conditions for teaching-learning processes [65], but include the entire academic institution, according to a holistic approach: in fact, it is a delicate mediating role between disciplines, departments, coordination and leadership roles, and links with the territory and the corporate world.

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The Role of Educational Interventions in Facing Social Media Threats: Overarching Principles of the COURAGE Project

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Abstract. Social media are offering new opportunities for communication and interaction way beyond what was possible only a few years ago. However, social media are also virtual spaces where young people are exposed to a variety of threats. Digital addiction, discrimination, hate speech, misinformation, polarization as well as manipulative influences of algorithms, body stereotyping, and cyberbullying are examples of challenges that find fertile ground on social media. Educators and students are not adequately prepared to face these challenges. To this aim, the COURAGE project, presented in this paper, introduces new tools and learning methodologies that can be adopted within higher education learning paths to train educators to deal with social media threats. The overarching principles of the COURAGE project leverage the most recent advances in the fields of artificial intelligence and in the educational domain paired with social and media psychological insights to support the development of the COURAGE ecosystem. The results of the experiments currently implemented with teachers and students of secondary schools as well as the impact of the COURAGE project on societal changes and ethical questions are presented and discussed.

Keywords: Virtual Learning Companion · Social Media Education · Artificial Intelligence · Societal Changes

1 Introduction

Social media is defined as "computer-mediated communication channels that allow users to engage in social interaction with broad and narrow audiences in real time or asynchronously" [1]. They are an integral part of our everyday lives offering diverse opportunities for communication and interaction way beyond what was possible only a few years ago. 98% of young users between 15 and 24 years use the Internet daily [2]. Most

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of them (96%) use social media, where they share experiences, opinions, and news. According to a representative study with 1,316 U.S. teenagers aged between 13 and 17 shows that the most frequently used social media are TikTok, Instagram, and Snapchat [3]. These networks are used even more often than a few years ago. While in 2015 52% of teenagers used Instagram, 62% of teenagers are using Instagram in 2022. The usage of Snapchat increased from 41% to 59%. TikTok, however, was not available in 2015 which is why we cannot report an increase from that time. Still, it is the most prominent "classic" social network nowadays, with 67% of teenagers using it. The use of Facebook significantly decreased from 71% in 2015 to 32% in 2022. The only social media platform that is used more than TikTok is YouTube (95%). However, the usage patterns on YouTube differ slightly from those of TikTok, Instagram, and Snapchat, where direct communication between users is more important than on YouTube.

The ubiquity and usage intensity of different social media platforms causes that even children and adolescents are profusely confronted with very heterogeneous, and sometimes harmful content. Content, network and algorithms are factors of social media that may also represent threats for (young) users. Such threats can be digital addiction, discrimination, hate speech, misinformation, and polarization, manipulative influences of algorithms as well as body stereotyping or cyberhate and cyberbullying [4].

Consequences of engaging with such toxic content and dynamics can range from negative affect, reduced well-being, and emotional problems to severe depressive symptoms and suicidal thoughts [5–8]. Furthermore, victims of cyberbullying or aggression might become a bully themselves as a kind of exit strategy [9]. Notably, victims as well as bullies suffer from the bullying situation [10], and both are shunned from their classmates [11]. It becomes clear that bullying (as an example for toxic dynamics) affects a whole social environment instead of only the victim and the perpetrator, for instance the class in school. This can harm the cohesion and healthy group dynamic in class and beyond.

Young users can be overwhelmed by the flow of content and do not know how to protect themselves from harm or how to help other users (see [12]). Consequently, the educators, caregivers, and social organizations (among others) are challenged to help students mitigate risks by conveying critical skills and social media literacy. Notably, we do not want to ban the use of social media at all. This would not be a realistic approach since social media are ubiquitous and users also say that they would have a problem with quitting social media. More precisely, 54% say that it would be "very hard" for them to stop using social media, 18% say it would be "hard", and another 35% say it would be "somewhat hard" [3].

A more promising and sustainable approach is to raise awareness of this issue and to increase social media literacy. When teaching social media literacy, which includes "decoding, evaluating, and creating" social media content [13], it is important that users' are not only provided with information or pre-defined solutions to a problem, but that they learn how to implement strategies and adapt their knowledge to different contexts and situations [14]. Thus, it is not only about factual or declarative competence, but also about procedural competence [14–16]. This approach goes hand in hand with increasing critical thinking abilities of users. Further relevant aspects for developing social media literacy cover self-protection skills, emotional intelligence, empathy, and should be driven by intrinsic motivation. In all the mentioned endeavors it is crucial to not violate users' autonomy. However, developing social media literacy and self-protection skills needs time and effort. As long as students do not have sufficient skills for acting fully self-determined, they need support (without coercion). This support can be provided by interweaving technical tools with guidance by educators, ensuring students' autonomy, increasing their competence, and providing an experience of social relatedness (see self-determination theory, [17]).

In line with this, teachers and educators have an increasing responsibility in providing and implementing learning activities that stimulate reflection on the mechanisms behind the use of social media [18, 19]. However, most of them are not adequately prepared to face these challenges, and, consequently, there is an increasing need in providing educators with new methodologies and tools specifically designed for these purposes [20]. Teacher education would benefit from including critical social media literacy since social media spaces are not neutral and students need strategies and tools to leverage the opportunities emerging in these spaces [19, 21]. In [22], for instance, the ecological system theory has been leveraged to affect the school microsystem and assist students through specific training activities and innovative tools in understanding the mechanisms and algorithms of social media platforms with respect to toxic content propagation, content recommendation and personalization. In the following, we will a) report findings from psychological literature demonstrating the severity of cyber aggression and its impact on users' well-being, and b) refer more detailed to the role of educators for increasing students' social media awareness and self-protection skills, then we c) introduce the COURAGE project[1], in which a social media companion safeguarding and educating students is proposed, aimed at supporting educators in promoting innovative educational interventions to increase students' awareness on social media mechanisms and the consequent threats that in these environments proliferate. The impact of the COURAGE project actions in educational practices is finally presented.

2 The Severity of Cyber Aggression for Social Media Users

The systematic review in [4] points out, there is no comprehensive and commonly adopted definition of cyberbullying and/or cyberhate. Thus, we refer to any form of cyber aggression on social media (e.g., cyberbullying, hate speech, fake news) when talking about toxic content on social media in our project. However, we argue that it is important to be very clear about the definition of cyber aggressive behavior when analyzing it in an empirical study in order to be confident about the causes and effects.

Cyberbullying interactions on social media can be particularly damaging because they are permanent, easy to spread, and can appear at every time of the day, making monitoring and moderation a particularly expensive task also from the psychological side [23]. Moreover, teenagers may spend a substantial amount of time on social media, which can strongly affect them not only as victims or bullies but also induce a change of attitude as a consequence of observing such events.

Prior studies measuring the impact of cyberbullying, for instance, showed that bullying on social media can be related to severe problems such as lower self-esteem,

[1] https://www.upf.edu/web/courage.

perceived loneliness, psychosomatic or depressive symptoms [24–26]. The influence of both, cyberbullying, and bullying in schools disentangled from social media has been investigated in [27]. Both forms of bullying were revealed to be severe risk factors for post-traumatic stress symptoms of adolescents between 11 and 18 years ($\mu = 15.6$, $\sigma = 1.89$). Notably, many cyberbullying scenarios have their origin in disputes in the classroom, or, the other way around, bullying in school contexts can be expanded to social media and reach an even larger audience. Therefore, it is even more important to take effective action against cyberbullying and cyberhate that could contrast the extended exposition that unprepared teenagers can have online. Schools are the perfect place to raise awareness about the three shared characteristics of cyberbullying and bullying outside social media: aggression, power imbalance, repeated behavior [28], and also about social media features which are actually able to reinforce cyber aggression (e.g., perceived anonymity, increased number of bystanders, persistence of the bullying content, and continuous access to the platform). However, providing sustainable additional support outside of the classroom is also likely to be necessary especially for the most fragile users.

Authors in [29] investigated the effects of hate speech by means of six million comments on Reddit provided in 174 online college communities and revealed that being confronted with hate is related to increased expression of stress. However, their results also reveal that the effects depend on individual characteristics of the users, for example, their psychological endurance (i.e. resilience). Resilience comprises adversity and adaptation, and can be more or less stable [30]. However, it definitely is an important factor for dampening the effects of cyber aggression. Authors in [31] also investigated the role of resilience in the context of hate speech and found that resilient hate speech victims report lower depressive symptoms than victims with lower expression of resilience.

Besides the severe influence on adolescents' well-being and psychological health, toxic dynamics on social media are also related to poorer academic performances. Kowalski and Limber in [28], for instance, showed significant correlations between poor grades, absence from school, quantity of leaving school on the one side, and being involved in cyberbullying (as perpetrator or victim) on the other, for students between 11 and 19 years ($\mu = 15.16$, $\sigma = 1.76$). Here, we need to take into consideration that authors in [28] report correlations instead of causal effects. Thus, it is actually not clear whether bullying leads to poor grades, or poor grades have an impact on bullying. Nevertheless, acting against bullying – no matter on which side of the causal chain – can help to overcome a toxic relationship.

When looking at cyber aggression on social media, there is not only one perpetrator who is the reason for the spread of toxic content, the bystanders play a significant role as well. Users who are observing cyberbullying scenarios, hate speech, discrimination or other harmful dynamics on social media without taking action might contribute to the spread of such content, albeit involuntarily and without malicious intent. Studies reveal that the intention to intervene in problematic scenarios is related to users' empathy and the perceived similarity to the victim [32]. Thus, if the bystander is able to mentally put himself in the other person's place, there is an increased possibility that the victim receives help from the bystander. Therefore, empathy and emotional intelligence are severe factors for acting against toxic dynamics on social media. According to a large meta-analysis covering 146 different definitions of empathy by Guthridge and Giummarra [33], empathy can be defined as "the ability to experience affective and cognitive states of another person, while maintaining a distinct self, in order to understand the other." Emotional intelligence resembles, amongst others, the ability to understand the emotions of other people, to use emotions to facilitate decision-making, and to manage emotions [34]. Interestingly, emotional intelligence itself was already shown to be positively related to mental health, well-being, and academic performances [34, 35]. Thus, it is not only important for preventing cybermobbing, but for educational contexts in general. An important aspect is also the ability to effectively react for a victim of cyberbullying and intervene in their support, as ineffective reactions may worsen the situation. Indeed, different aspects of emotional intelligence, (i.e. intrapersonal and interpersonal emotional competence) might play different roles and is important to provide specific educational support to develop each of them [36].

3 The Role of Educators to Increase Students' Social Media Awareness

The role of teachers in promoting social media, digital literacy and countering disinformation has been recently highlighted by the EU commission in the final report of the "*Commission expert group on tackling disinformation and promoting digital literacy through education and training"* [37]. In this report, initial teacher education (ITE) and continuing professional development (CPD) have been identified as fundamental elements to foster teachers' intervention. Also, educational online applications are crucial to support teachers in developing digital and media literacy competences. Innovative educational approaches and tools are needed to promote educational interventions aimed at providing students with the needed tools to counteract and face social media threats. For instance, in [38] researchers showed that students revealed an increasing ability to judge the credibility of digital content when they participated in lessons in which, by experiencing lateral reading, they learnt how to evaluate online content and identify fact news. This confirms the central role of educational interventions in changing the way students approach social media threats and improving their well-being in social media environments. Educational interventions specifically focused on addressing these challenges have to be designed and also teachers need to be empowered to include these interventions within their educational strategies.

The need to '*[empower] teachers so that they are able to take an active stand against all forms of discrimination and racism, to educate children and young people in digital literacy*' is a concept that has been proposed in March 2015 in the framework of the Paris Declaration of EU Education Ministers. The conclusions of the EU Council in May 2016 on the role of education concern how to provide learners with the competences and values required 'to access, interpret, produce and use information and other media content, notably in the context of the internet and social media, in a safe and responsible manner'. In September 2020, the Digital Education Action Plan (2021–2027) of the EU Commission stated that 'it is important to educate people at all ages about the impact of digital technology on well-being and the way technology systems work.' In the meantime, empirical investigations highlighted the need to empower teachers and educators so that they can support their students, as well (e.g., [18, 19, 21]).

The report by the EU Commission (2022) highlighted the areas of digital literacy which should be addressed more in education and training, specifically the need for further training of educators to acquire the competences needed to engage their students in creative ways, the need to develop digital tools and environments not only for educational purposes, but also to promote individual and social well-being.

In this direction the COURAGE project provides solutions which can be introduced and implemented by educators in school contexts, until students are able to use the tools on their own, or – in the long term – until they have sufficient social media awareness, social media literacy, and self-protection skills. Importantly, we provide information, user friendly interfaces, and workshops that are helpful for both students and teachers.

4 The Courage Project

In the framework of the COURAGE project, the multinational and multidisciplinary team provides educators with new tools and learning methodologies that can be adopted within higher education learning paths to train educators in supporting students in facing the social media threats. The multidisciplinary nature of the project team was leveraged to face the problem from different perspectives. In particular, we propose novel approaches exploiting most recent advances in the fields of artificial intelligence and in the educational domain paired with social and media psychological insights. The basis for the tools and training-scenarios provided by the COURAGE project is a complex technical development resulting in the conceptual architecture described in [39]. Building on that, and on research questions and hypotheses derived from prior literature, various scenarios have been created and empirically evaluated by the project team. In the following, we will provide a compressed overview of the technical development (see also [39]), also referring to the role of AI, and then refer to some of our empirical investigations which are explained in more detail in [40].

4.1 AI, Media Literacy, and Societal Changes in the COURAGE Project

Artificial intelligence (AI) proposes new opportunities in educational support systems, but poses challenges (e.g., privacy threats, manipulation, threat to autonomy) and promising outcomes (e.g., suited user support) at the same time. AI can be viewed from different perspectives – for instance how it provides content to social media users in their social networks (by means of algorithms for microtargeting or recommender systems), how it provides information to users through a smart speaker device, or how it might help to improve the performance of technical tools for supporting users regarding a non-harmful social media use.

The influence of AI technologies in several aspects of media content production has led to the need of promoting media literacy education interventions aimed at unveiling the mechanisms at the basis of algorithm-driven media. To this aim, educators should elaborate specific learning paths connecting media literacy education and computing education [41].

In fact, if from one side the issues related to social media have been identified, from the other side there is a lack of appropriate educational interventions able to face the social media challenges and support students in developing the needed media literacy skills. In the framework of COURAGE specific tools and methodologies have been designed to this purpose, with the aim to provide educators with a comprehensive toolbox combining both technological support and also pedagogical strategies. The aim is to better address the issue of increasing awareness of students on social media threats. In this perspective, the approach proposed in COURAGE brings the educators towards the challenges that media literacy poses in the machine learning age. As stated by Valtonen et al. in [41], topics such as dynamic content generation, recommenders and optimization, content filtering, attention engineering, reinforcement learning are directly related to educational content aimed at developing skills and knowledge about how artificial intelligence applications operate behind social media platforms.

The research on artificial intelligence in higher education needs to provide more insights on how to progress on the pedagogical models and how effectively AI can support higher educational teachers to make teaching and learning more effective [42]. The categorization of AI applications proposed by Zawacki-Richter in [42] identified four categories: application for profiling and prediction, application to support assessment and evaluation, adaptive systems and personalisation, and intelligent tutoring systems. The COURAGE conceptual framework provides different contributions in these four areas with specific modules, in which the interconnection between the theoretical pedagogical strategies and the educational application of AI approaches plays a relevant role [43].

In our project, we consider AI as a chance to provide adequate support for users by focusing on the advantages of new technologies in a digitalized society. However, the potential threats of using AI as well as risks associated with AI used to manipulate users in social media environments shape our ethical and moral understanding regarding responsibilities that come along with the consideration of AI-based systems.

As AI algorithms of social media platforms do not directly counter threats for teenagers but may actually worsen and amplify them, in the COURAGE project we propose the adoption of a virtual learning companion (VLC) powered by an AI system that counters these threats and the platform specific algorithmic hazards [43]. The VLC AI system developed comprises adaptive detectors of content and network threats, user models to support personalized interventions as well as content and educational activity recommendations.

The VLC also supports educators in empowering teenagers regarding the threats in social media by developing social media competences and self-protection skills. A particular emphasis was put on the role that experts and educators play in the management of the VLC by driving and moderating the use of it in classroom-based educational activities as well as providing learning strategies, objectives and activities implemented in the VLC [43–45]. In the next section we present how the VLC has been piloted in real scenarios through different educational interventions.

4.2 Transfer of the Virtual Learning Companion into Practice

The current version of the COURAGE eco-system has been experimented in several studies with teachers and students of secondary schools. Overall we can rely on workshops, discussions with around 500 experts and students, as well as empirical studies, in Italy, Spain, and Germany.

The aims of these investigations were and still are to:

a) analyze the effects of training activities about social media mechanisms (algorithms and social influence),
b) support understanding and dealing with different types of threats (misinformation, filter bubbles, hate speech, ethnic and body stereotypes),
c) encourage a constructive use of social media,
d) assess procedures aimed at analyzing psychological characteristics of adolescents in correlation with social media use such as mental well-being, emotional intelligence, critical thinking, life satisfaction and resilience,
e) implement scenarios of educational interventions through narrative scripts, minigames, and educational content design.

Overall, the technical environments and empirical studies demonstrate the feasibility and encouraging positive impact of the approach. In the following we will report some of the empirical investigations that have been conducted. For instance, gamification (i.e. "the use of game design elements in non-game contexts" [46]) strategies based on the concept of interactive narrative and counter-narrative (i.e. scripts that challenge previously made assumptions) scripts, have been implemented to support learning scenarios. In our studies, students were immersed in social media stories that exposed them to counter-narratives and conversations about counter-narratives, about biases, discrimination, or attitudes and behaviors in what (and how) is spread online [47]. These components direct content recommendations and educational interventions, such as triggering specific validation tests that improve the accuracy of user state estimation as well as progressing in narrative scripts, which are gamified educational activities based on the concept of interactive counter-narratives. Scripts and material were evaluated positively and were related to high levels of intrinsic motivation ($\mu = 4.41$, $\sigma = 1.25$) and low levels of perceived pressure/tension ($\mu = 2.52$, $\sigma = 1.21$), both on a 5-point Likert Scale. Against the background of self-determination theory [17] and AI guidelines stating that it is important and necessary to guarantee users' autonomy, this is a satisfying result. This also resembles an important aim of the COURAGE project, namely, providing support without using paternalistic approaches, allowing for the development and enhancement of users' interdependent self-protection skills. Not using paternalistic approaches means respecting users' autonomy and self-determination through leaving the final decision and behavior to the user. Our approach shall guide the user towards the right (i.e. less harmful) direction, but not force her to perform or not perform a certain activity. A specific game based educational activity allowed students to directly experience and grow aware of the effects that phenomena like echo chambers and filter bubbles can have on their perception of the world and their decisions. This is particularly important as these phenomena are usually almost imperceptible for the users [48]. Further empirical works are reported by [40].

The efficiency of more advanced, multi-step user specific, algorithmic interventions, e.g., content and connection recommendations, to a) counter network and algorithmic threats, b) support the achievement of educational targets, and c) improve the collective well-being of the user community is currently supported by simulations based on collected data and validated user models [43].

In particular, we studied the relationship between users' satisfaction, content diversity exposure and collective well-being metric through the simulation of three different recommender systems using three different strategies to: maximize opinion diversity, overlapping third order neighborhood and random recommendations. Satisfaction is assumed as a proxy for the sustainability of the social media platform. Content diversity exposure could play an important role in countering the effects of filter bubbles [49], echo chambers [50], and ultimately society polarization. The recommender that maximizes the diversity of opinion between the pairs of users to connect showed a slower start but achieved higher exposition to more diverse content and a similar level of satisfaction to the other two recommender systems.

5 Impact of the COURAGE project

The COURAGE project highlights the relevance and urgency of raising users' awareness of social media threats, increasing their social media literacy and self-protection skills by means of both technical support and assistance to educators who can make use of tools developed within the project. Figure 1 provides a summary of the most relevant aspects of the COURAGE project, highlighting the role and application areas of educators. It shows that the interaction with the VLC (within the social media environment) is the starting point of the process aiming at developing and establishing self-protection skills of students. In a first step, the VLC helps students to develop and train a) relevant personal skills like empathy or emotional intelligence, b) social media / digital skills like using reverse image search for identifying the origin of a manipulated picture or considering specific (privacy) settings within a social network, c) knowledge regarding toxic content such as reasons and quantity of discrimination on social media or the severity of promoted "perfect" body images. These skills then should increase social

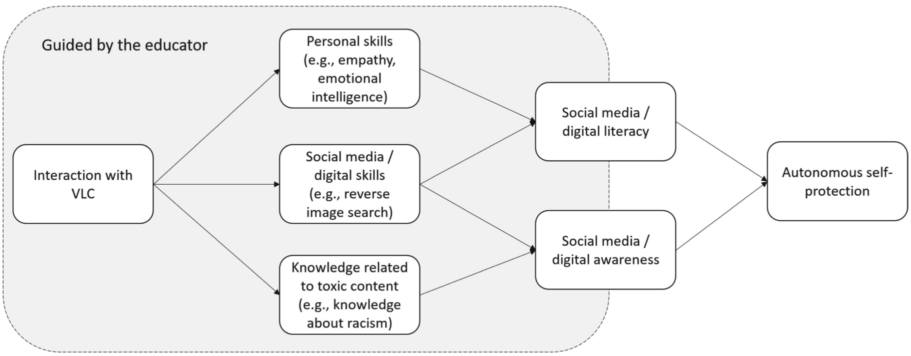

Fig. 1. Conceptual overview of the aims of the COURAGE project

media awareness and social media literacy and finally, students' ability to autonomously protect themselves against the threats of social media. Educators should support the students in this process by introducing the VLC and related tools and accompanying them until they have sufficient skills to either use the VLC autonomously or until they are able to protect themselves, even without the VLC.

In addition, the project emphasizes the responsibility of teachers who would benefit from technical support when educating their students with regard to social media literacy. Besides having social media literacy themselves, educators also need to know how to transmit factual and procedural knowledge regarding a safe use of social media. Transmitting this knowledge to students is a responsible and far-reaching task, because it will affect users' everyday as well as future life. Therefore, it is important to offer workshops and sophisticated accompanying material for educators who are confronted with this important duty. In fact, the success of transmitting social media literacy in educational contexts strongly depends on the educators' skills and knowledge [51]. Since schools nowadays often are working with digital devices, training social media literacy should be a fixed component of curricula. Here, students and teachers could start working with the VLC and narrative scripts and continue using it in their everyday lives outside of school. COURAGE focuses exactly on these interwoven aspects: addressing young users *and* educators, which is an advantage in comparison towards other approaches focusing on students *or* educators. And instead of simply providing tools and materials, the project teams are going to schools in order to conduct workshops and receive qualitative feedback from students and teachers.

Current developments such as the increased use of social media due to the worldwide COVID-19 pandemic [52] reveal an even higher demand for action in this realm. Studies show that students are engaging with social media more often and more intensely since the outbreak of the pandemic (e.g., [53]). At the same time, parents, educators and caregivers had and still have plenty of other responsibilities so that children were and still are often alone with their social media, aggravating the threat of toxic content.

Furthermore, with our project, we are facing huge challenges in terms of normative and ethical questions. This has several reasons.

First, we are addressing young users who are in a sensitive phase of their lives and whose identities are still developing. Following the psychosocial theory by Erikson [54], adolescents deal with identity formation and identity confusion. This includes exploring and perceiving the social surrounding, learning from it, and developing attitudes and patterns. Depending on the social surroundings, role models and references can foster either a social, critical and empathic direction of development, or a toxic development. Since social media are an integral part of adolescents' social life, there is a huge range of role models, examples and circumstances which might be an anchor point for them in their development. Here, we see the need for supporting users when facing toxic content and dynamics in order to provide more space for positive and meaningful experiences on social media which might be beneficial, or at least less harmful than discriminating, offending or manipulated content.

Second, we are working with AI, which brings several ethical challenges itself. The use of AI algorithms is connected to new types of ethical issues, when the algorithms are trained on biased data they will produce, in turn, biased output. Therefore, they cannot be considered impartial and their effects on discrimination, prejudice and stereotypes are amplified, and this is even worst when it comes to AI algorithms that regulate social media mechanisms, since these algorithms influence the ecosystems in which young adolescents grew up, thus often providing the lens through which adolescents shape their understanding on new concepts.

Third, when it comes to content on social media, it is really hard to decide what is acceptable and what is not. Who determines the border between good and bad? For some people, a posting might be severe and offending, for others not. Thus, it is not easy to overarchingly categorize content depending on its severity and harmfulness. Consequently, the indicators initiating assistance by the VLC need to be chosen very carefully. Besides setting the baseline for when to intervene and support, working with AI systems needs to consider further aspects like privacy protection, fairness, transparency, or common good [55], to name just a few.

6 Conclusion

We have already achieved important goals, since first qualitative and quantitative evaluations show that the VLC and the different VLC scenarios can support students as well as educators, by providing information, increasing skills and motivation, and training social media literacy as well as raising awareness of users. Users' experiences in schools or social environments can affect their experiences on social media and the other way around. Thus, we are dealing with an overarching challenge for students' everyday life and their future. We want to "make social media a good place", to improve the overall experience of social media and help students in developing self-confidence in digital spaces and beyond.

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Yes, Echo-Chambers Mislead You Too: A Game-Based Educational Experience to Reveal the Impact of Social Media Personalization Algorithms

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Abstract. We present a digital media literacy activity composed of (i) an educational talk and (ii) a game-based activity. The aim is to support teachers in developing learning activities to increase awareness of social media threats among students. Through this activity students directly experience phenomena like echo chambers and filter bubbles that can be provoked by harmful online interaction dynamics controlled by social media platforms' recommender systems while remaining invisible to the affected users. Our preliminary findings show that a game-based direct experience, inspired by the wisdom of crowds phenomenon, can increase the perception of social media influence on participants with statistically significant results compared to standard lecture-based activity. We conclude that developing a tool enabling educators and scholars to easily perform the proposed activity can be helpful to improve digital media literacy effectiveness.

Keywords: Media Literacy · Social Media · wisdom of crowds

1 Introduction

Social media won the competition between traditional (radio, television, newspaper) and new media such as Facebook, TikTok, Instagram, Twitter, Snapchat, and YouTube. Nowadays, the news and entertainment arena is dominated by multi-sided platforms (where each side is a different type of customer to whom services are provided) characterized by user-generated content and the absence of an editorial board.

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The low cost of devices and infrastructure (smartphones and internet access) together with network effects[1] [1] led to a capillary adoption of social media with skyrocketing increases in adoption rates since 2005. Today, based on Pew Research data[2], an average of 72% of U.S. citizens claim to have at least one social media account. This percentage rises to 95% when it comes to adolescents and 45% of them report to be almost constantly online[3]. Platforms such as Instagram, TikTok and Facebook are becoming not only a relevant source of entertainment but also of information. As reported to Fortune by Prabhakar Raghavan, a Google senior vice president, a share of young users are starting to use TikTok to find everyday information such as restaurants, and news. These services are replacing the once previously offered only by search engines[4].

Even though social media can be an efficient way of finding information, they have allowed the emergence of negative phenomena that may harm users. The dramatic increase of information users resulting from social media introduction and their lack of regulatory framework or ineffective implementation[5] have the capability to skew the content presented toward specific topics or sources [2]. Such capability is due to the platform's information personalisation systems that are used to simultaneously satisfy their diverse public. Information personalisation may lead users into a filter bubble, an informational situation introduced by Parisier [3] where users are provided with only a part of the spectrum of the information available. Moreover, this combines with the social component of the media escalating homophily, the human natural tendency to form self-referential groups, which have been named echo-chambers [4–6], that may cut external feedback and result in social polarization and fragmentation.

This algorithmic operated distortion of information and perceived reality is difficult to detect making it even more dangerous. When the users are unaware of these mechanisms they can more strongly adopt the distorted reality they are presented with and can inadvertently extend its impact creating dangerous feedback loops between users and algorithms. However, social media users, teenagers in particular, which are between the most vulnerable, have still limited knowl-

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1 Direct and indirect network effects are one of the main futures of platforms and can be defined as the fact that a platform service gains more value as more people use it. A direct network effect means that if more friends join the network, e.g. Facebook, each user will gain more utility from using it because he can keep in touch with all of his friends. Indirect network effects mean that e.g. if more vendors join Amazon each buyer will on average gain more utility e.g. because he has more chance to find the needed good.

2 Find the Table in Social media use over time in https://www.pewresearch.org/internet/fact-sheet/social-media/, Retrieved on March 2, 2023.

3 Source: Pew Research Center https://www.pewresearch.org/fact-tank/2019/08/23/most-u-s-teens-who-use-cellphones-do-it-to-pass-time-connect-with-others-learn-new-things/. Retrieved on March 2, 2023.

4 Check here https://www.nytimes.com/2022/09/16/technology/gen-z-tiktok-search-engine.html. Source: New York Times. Retrieved on March 2, 2023.

5 Mozilla released a report called *YouTube Regrets* that highlights how YouTube recommender system cannot act coherently with user's preferences regarding undesired content https://foundation.mozilla.org/en/youtube/findings/.

edge of such phenomena [7]. Thus, it is crucial to develop effective educational activities that will rise (new) media literacy of students and users [7–9] improving their understanding of the algorithmic, social, and psychological mechanisms underlying social media to promote a conscious and critical approach to their use.

We propose that preliminary training concerning social media threats is needed for students and that merging traditional educational activities with a guided, direct, and game-oriented experience of social media threats could be an effective method to raise students' awareness of the impact of complex phenomena, such as information personalisation, social influence, filter bubbles, and echo chambers [4,10].

We thus adopt a game-based approach and introduce a strategy that offers students a direct experience of some drawbacks of information personalisation. To mimic the negative aspects of social media such as filter bubbles and echo chambers without causing harm to participants, we leverage the well-known **Wisdom of Crowds (WOC)** phenomenon [11,12], that allows to mimic echo chambers and filter bubbles given the "black-box" manipulation of the information that is shown to participants.

1.1 Why Wisdom of Crowds

Wisdom of crowd is a feature of the outcome of many individuals independently estimating a quantity, where the median values will be more accurate than a single expert. In a sequential decision task this implies that estimators can access peers estimate, introducing information from them. This stage is the proxy we will use to simulate information personalisation and its drawbacks, namely a filter bubble and an echo chamber.

In brief, the participants are presented with a repeated visual estimation task where in each trial they also have access to social information, that is, an aggregate view of other participants' responses. This social information may modify, improve or distort participants' estimates. In addition to this, to simulate and educate about the effect of information personalization, we then purposefully skew this social information in half of the trials.

In the following section, we contextualize our work concerning teachers' support in developing learning activities to increase awareness of social media threats among students by exploring digital media literacy among teenagers, recommender systems on social media and the wisdom of crowds phenomenon. Afterwards, we describe the components of the experimental protocol in Sect. 3, and the results of our experiments in Sect. 4. Finally, in Sect. 5 we present the conclusions and future works.

2 Related Work

2.1 Digital Media Literacy and Teenagers

Teenagers represent the most common social media users, and education systems are starting to introduce digital media literacy in their curriculum [13] to educate students about digital citizenship as the proper and responsible way of using digital technologies [14], enabling users to critically approach social media and deal with its threats [15–19].

Understanding the impact of social media on their mental health and well-being is crucial [20–22] also because multiple studies highlight the strong and negative correlation between the usage of social media and self-reported mental health, suicidal intention, etc. Tsitsika *et al.* [23] also find a positive association between heavier social media use (more than 2 h/day) and anxiety and depression for a sample of European students.

During the COVID-19 pandemic social media allowed locked-down individuals to maintain connections, and as a consequence, the average time spent on these platforms increased. But as shown by Parlak *et al.* [24], the increase in time spent on social media by teenagers is a good predictor of their COVID anxiety score, finding also a correlation with social media addiction.

Moreover, specific social media features, such as unfriending, can accelerate the emergence of the so-called echo chambers [25]. As shown by Cinelli *et al.* [26], Facebook is found to be the social media platform where homophily and information diffusion generate the most correlated neighbourhoods in terms of opinion leaning, and Bail *et al.* [27] find that exposing Twitter users to opposite political views increases polarization.

A digital literacy activity was proposed by Choolarb *et al.* [28] that merges both an augmented reality tool and a gamified strategy. Results show that both in terms of satisfaction and learning goals the experimental group (pupils who get the augmented reality and game-based learning program) increased their performances with statistically significant differences in their evaluation with respect to the control group.

2.2 Recommender Systems and Social Media

To efficiently provide the most engaging content and needed information to social media users', platforms leverage machine learning systems trained using billions of examples taken from users' logs or other data sources. These algorithms classify, filter, and recommend content or other people in a personalised manner to each user. This personalisation step can belong to the Collaborative Filtering family, where users with similar interests are leveraged to find potentially interesting items for each user [29]. Alternatively, recommender systems can leverage content representations (in the form of numerical embedding or any feature that can be used to compute a similarity between two items) to find items similar to the ones liked or purchased by the user. Still, while maximising users' engagement, social media platforms may harm other stakeholders that use the platform [30,31]. Their recommender systems may exasperate users' tendency to connect and populate their virtual environment, or social sphere, with like-minded users and they may be served with content they already like [5,26]. Moreover, if users are unaware of the consequences of information personalisation their perception of reality may be more strongly distorted.

Boeker and Urman [32] pave the way to a better understanding of TikTok's recommender system. Findings show that certain factors influence the recommender system more than others, and point out how explicit factors (e.g. language, location, previously liked pages and creators) influence the recommender more than implicit factors such as the video view rate. It is crucial to highlight that ByteDance, TikTok's owner, had never released or opened to a third-party audit their recommender system to establish which are, for example, the relative weights of explicit and implicit feedback taken into account by their recommender, that is incidentally one of the main reasons of TikTok's success [33].

Besides the influence of algorithms, users can also reciprocally influence each other and the recommender systems can accidentally amplify negative dynamics. For example, they may increase or decrease the visibility of emotionally loaded content, but as shown by Kramer *et al.* [34] that studied the relation between users' exposure and user content production, when the exposition to positive expressions is reduced, people produce fewer positive posts and more negative posts. Furthermore, emotional and sentiment load in messages can itself affect the spread of content, as shown by Brady *et al.* [35] through modelling the diffusion of moral-emotional language in political content. These results indicate that emotions expressed by others on Facebook influence our own emotions and highlight that emotion contagion can take place on Facebook. Moreover, even if the exact role played by recommender systems and user selection in the creation of echo chambers isn't clear [36], it is crucial to enrich media literacy with specific notions and strategies to deal with these systems and issues [7].

2.3 Wisdom of Crowds

The phenomenon of the Wisdom of Crowds was discovered by Galton in 1907 [37], and a century later social media are challenging his findings. Forecasting and estimation tasks can get better accuracy from crowd-sourced answers rather than a single expert [38], and a crowd can be smarter using a collective decision making deliberation system [11,39].

The reasons why this can happen are grounded on the hypothesis of uncorrelated errors and enough diversity in the initial distribution of answers, so that even if the individual answer is far from the right one, an aggregation of answers will be more accurate [40]. It is clear that the Wisdom of Crowds is closer to a statistical phenomenon rather than a social feature, but social influence can undermine the hypothesis upon which this statistical phenomenon relies on.

This collective decision-making process, where participants are aware of others' estimates or answers and they can revise their answer can fail for many reasons. Social influence can reduce the efficacy of the wisdom of crowds given the fact that multiple factors can lead to correlated errors.

To address this interplay between social influence and individual conviction, Mavrodiev and Schweitzer [41] derive analytically the condition with respect to the initial error and diversity of opinions that determines an increase or decrease in accuracy under a decision model that includes social influence and individual conviction.

The effects of network structure on the performance of wisdom of crowds were investigated by Becker *et al.* [12] that proposed an experimental setup where two radically different but simple graphs are created. The first type of network was a centralized one: all the nodes were connected with only a few other nodes that had a disproportionately larger number of connections, generating a sort of a star graph, so all the nodes except the central ones have a degree equal to one. The decentralized condition was defined as networks where everyone has the same number of edges, i.e. connections. Participants were involved in a repeated estimation task, and the results confirmed the existence of the wisdom of crowds, because for the first estimate the mean answer was more accurate than that of the majority of the participants' individual answers. Also, between different estimates the mean of the estimates was more accurate and there was a reduction of the standard deviation. Furthermore, findings show a huge impact of network structure: the decentralized network has a positive effect on the overall accuracy while the centralized one is always skewed toward the direction of the central nodes. Analytical approaches such as that of Mavrodiev and Schweitzer [41] also argue that the wisdom of crowds is really a weak phenomenon and a small dose of social influence can heavily reduce the diversity of answers without ensuring an increase in accuracy. Moreover, the increase in confidence, i.e. the reduction in standard deviation, may be caused by a convergence that is not related to an increase in accuracy [41].

Literature shows that social influence and network structure deeply affect the wisdom of crowds, but individuals may still have other possibilities to coordinate and improve. Navajas *et al.* [39] study the role of group deliberation in parallel with social influence. The authors create a repeated estimation task that involves many individuals and then let them form small groups just after individual estimation to allow the group reaching a consensus and deliberate. Results show that if individuals are allowed to form small groups after the first estimation the possibility of deliberation within groups improved the crowd's collective accuracy.

The role that political bias and partisanship could play with respect to the wisdom of crowds has been investigated too. Individual motivations (e.g. political preferences) can affect our reasoning [42] and shape opinion about facts, so it is crucial to also test the wisdom of crowds hypothesis outside the context of nonpartisan estimation tasks commonly used for experiments.

Becker *et al.* [43] create political homogeneous networks and then perform a repeated estimation task to test whether social influence and political partisanship can affect the accuracy of nonpartisan estimation tasks and if during the estimation beliefs became more extreme instead of more accurate. Findings show that homogeneous networks are resilient to the propagation of partisan bias, so the wisdom of crowds in networks is robust to political partisan bias. The effectiveness of the wisdom of crowds has been tested also with respect to fact-checking by Allen *et al.* [44]. In this work more than one thousand participants have been recruited using Amazon Mechanical Turk, and findings show that a small, politically balanced crowd of people can match the fact-checkers' accuracy and agreement in a task of labelling news articles.

3 Experimental Methodology

The proposed experiment entails a game-oriented social estimation task inspired by the wisdom of crowds [11,37] inside an educational activity aimed at raising awareness about social media influence and information personalisation effects. 7 The experiment is preceded and followed by questionnaires. In the very initial step, a random and unique code was assigned to each participant to ensure data anonymity. In the pre-treatment questionnaire, we asked for socio-demographic questions and social media usage information. Both in the pre and post-treatment surveys we asked participants, using two items (namely: Perceived Influence on themselves and Perceived Influence on peers) on a 6-point Likert scale which is the perceived influence of social media. The activity was designed to last no longer than an hour and a half to avoid the participants becoming mentally fatigued when filling out the final questionnaire. Each step of the protocol is depicted in Fig. 1.

First, a digital media literacy talk was given to students, after which participants were involved in a game organized as a repeated estimation task. In the game, different information scenarios were tested [12,39]. In the first, between trials, the students were given the correct aggregate of the crowd's estimate, while in the second they were presented with a biased one, i.e. skewed towards the wrong answer.

Our intuition is that through direct exposition to one of the most impacting echo-chamber and filter bubbles consequences, i.e. when biased sampling distorts users' unbiased opinions, followed by its explanation, the students can reason about the role that information personalisation has had in misleading them and will become more aware of these mechanisms and their effects. To discuss the results we also stress the metaphor of a "recommender system that selects the responses most relevant to the majority of users" adopted in the game.

For comparison, we also performed a baseline educational activity that comprised only the digital literacy talk followed by a the post-treatment survey. This means that the focus of the experimental condition with explanations of the proposed game and its impact is at the core of ou research questions.

Given the pandemic situation, the educational activities were performed remotely, with students present in the classroom, and researchers connected through a video conferencing software.

A pilot experiment was performed for the first time involving Computer Science master's students from the University of Milan-Bicocca.

3.1 Digital Media Literacy Talk

The digital media literacy activity has been developed to raise students' awareness concerning social media threats and empower them [18]. The goal of the digital media literacy talk is to contextualize the relevance and impact of information personalisation [7] and its applications such as recommender systems to point out their potential pitfalls and biases [45].

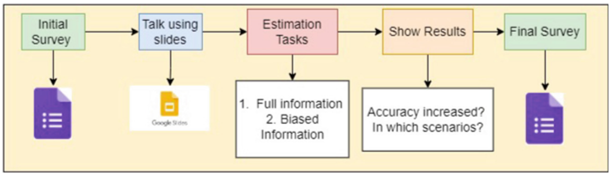

Fig. 1. The proposed experimental protocol. The total expected time for completion of the activity is 1h and 30 min.

The digital media literacy talk covers the differences between traditional media and social media with their complexity and pervasiveness, the impact of cognitive biases, and, finally, their interplay with information personalisation algorithms, highlighting the concepts of echo chambers and filter bubbles. During the talk, slides were used as a teaching tool.

The structure of the talk is detailed below and in Fig. 2 a sample of the slides showed to students is reported:

- Disintermediation: we introduce to the user a pivotal player in social media, the prosumer (both a consumer and producer of content). New media do not have an editorial board and content can freely spread around the network.
- The Network Structure: we present different graph structures to highlight the different "roles" that nodes can have as bridge for information spreading between friends and how each user affects their friends through their behavior (liking, sharing). We also show that the network dynamics is complex to predict as shown by the unexpected popularity of some content.
- To introduce **virality** we addressed the narratives and stereotypes that are more common in viral content, but we also highlighted how this model can negatively affect users, especially teenagers who aim to get popular on social media.
- Information personalisation is introduced as a helpful tool to overcome information overloading. An intuitive description of the principles of recommender systems if given to students to better understand the concept of filter bubbles.
- Echo chambers are explained as a difficult to observe phenomenon that may lead to social fragmentation and polarization and may be exasperated on social media given the partial and skewed representations provided to users by information personalisation systems.
- We also introduce backfire as a way algorithms can increase polarisation when exposing users to opposite and extreme content causing a vigorous reaction in users.
- We also present cognitive bounds and biases, e.g. homophily, that may be causes alternative to algorithms of polarization and other issues observed on social media.
- Conclusive remarks regarding the opacity and the lack of transparency by social media companies were presented.

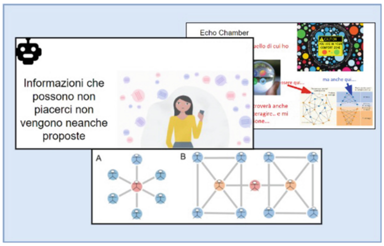

Fig. 2. Sample of the slides presented to participants.

3.2 Wisdom of Crowds Game Experience

While the **baseline scenario** ends after the digital media literacy talk, in the **experimental scenario** the wisdom of crowds inspired game followed, and a brief introduction was given to the participants. The game is executed as a repeated visual estimation task with an information personalisation step. The goal for each participant is to give the right answer with the possibility to revise their answer once after being presented with social information, e.g. in the form of an aggregated biased or unbiased peers' votes [39].

The first step of the WOC experience is to show students an image populated with red dots in random locations over a white background, as depicted in the top right of Fig. 3. This task is independent of the level of individual knowledge, differently from the study by Navajas *et al.* [39].

The second step of the game is the **individual estimate**. Here students can choose their answer between different ranges of values. The social information displayed to them is an aggregation of all the answers for that trial, and we opt to show an histogram of all participants' answers.

In the **correct feedback** condition, the aggregate is taken of the whole set of answers, while in the **biased feedback** condition, the aggregate is taken over a subset that exasperates the current error. The metaphor here is that this biased set is selected by a black-box recommender system that selects the responses most relevant to the majority of users.

After the information disclosure participants can revise their estimates and they have the possibility to give a second individual answer. We perform a total of four trials with each batch of classes, where half of them were correct and the other half biased.

In terms of users' response precision, according to previous studies [11,12] it is expected that in the correct feedback condition the second estimate will be more accurate than the first [39], while in the biased feedback condition it is expected to decrease. In Fig. 3 the protocol of the game is reported.

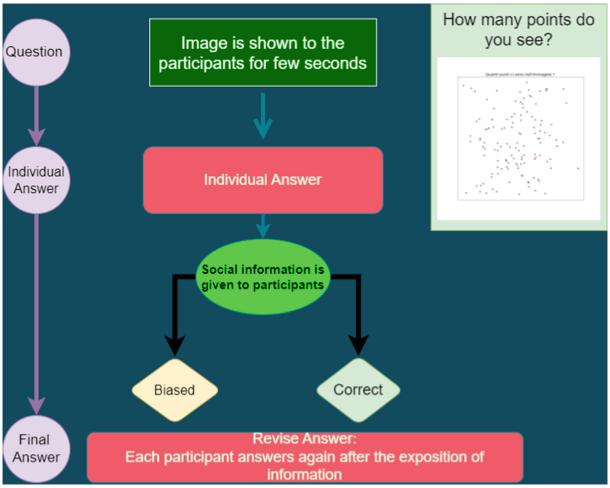

Fig. 3. Structure of the game-based wisdom of crowds estimation task. It starts with the question where the image on the top right is shown and they are asked to estimate the number of dots in it. After the aggregate of individual answers, as social information, is disclosed to the participants they can provide the final answer.

4 Results and Discussion

The data reported refer to two sessions, one for baseline and one for the full experiment, that involved separate classes of the high school ITET G. Caruso in Alcamo (Italy). All participants were between 18 and 21 years old (N = 52, Mean = 18.7, Standard deviation = 0.85). The activity is not designed for the specific curriculum of the school involved but participants were previously involved in educational activities during the civic education course.

In Table 1 the average answer for both scenarios and both items is reported in the initial and final questionnaires. Only in the **Experimental** scenario, when results are shown to students, there is an increase in the average perception.

We compute for each session (Experimental and Baseline) and each item proposed (perceived influence of social media on them or their peers) the difference between the initial and final answer for each participant. We then compute the number of participants with an increase (positive difference) and decrease (negative difference) between the initial and final item. Then for each item about perceived social media influence (on themselves or their peers) we compute Fisher's exact test and p values are reported in Table 3.

Table 1. Perceived Social Media Influence before and after the intervention. Columns Self and Other represent the target of the question related to perceived influence of social media on themselves or their peers. Values in cells correspond to the average, while sample size is reported in brackets.

Perceived Social Media Influence (Number of Participants)				
Target	Self		Other	
Phase	Initial	Final	Initial	Final
Experiment	2.89 (19)	3 (18)	3.74 (19)	3.89 (18)
Baseline	3.08(32)	2.66 (32)	3.86 (32)	3.69 (32)

In Table 2 the contingency table for each item proposed to students, namely the perceived social media influence on themselves and on their peers, is reported and used as input for Fisher's test.

We opt for the Fisher exact test because it is suitable when dealing with small sample size such as in our case. The test assesses the null hypothesis of independence between two proportions.

It is clear that in the experimental condition a great majority of participants showed a positive difference between the final and initial survey in both items (perceived social media influence on themselves and perceived social media influence on peers).

We compute the Fisher test for each perceived influence' items considering the not complete answers too (left column of Table 3). The p-values allow to reject the null-hypothesis that the two classifications are not different with a significance level of 0.05.

Table 2. The table reports the contingency tables for each item proposed (Perceived Influence on themselves and Perceived Influence on peers). In each row, the number of participants with an increasing (decreasing or not answered) difference between the initial and final survey is reported for each condition (baseline and experimental).

	Influence on self		**Influence on peers**	
	baseline	**experiment**	**baseline**	**experiment**
increase	10	9	11	10
decreasse	16	3	14	2
not answered	3	13	3	13

In the baseline condition, even if the mechanism and drawbacks of social media are explained to the participants, the traditional educational activity alone is not capable of increasing the perceived influence of social media. We hypothesize that the proposed game is a good metaphor for the black box recommender system's mechanisms. In our setting, users have no control over it and are not informed about the adopted strategies.

Table 3. The table reports the p-values for each item in the survey (rows). Columns report both cases where unanswered questions are either considered a decrease or a class. Incomplete cases are included to test if considering them a third class the outcomes of the Fisher test change given the low sample size.

P values Significance Level .05		
	Both Answers	**Not complete**
self	**0.000596**	**0.015742**
peers	**0.000441**	**0.00604**

5 Conclusion and Future Works

In this paper, we have described a Digital media literacy activity composed of an educational talk alongside a game-oriented strategy to increase the efficacy of educational interventions regarding social media threats [46]. The aim is to boost awareness of social media threats allowing students to directly experience phenomena such as echo chambers, filter bubbles and their consequences that may be exacerbated by automated systems such as recommender systems.

Results presented in Sect. 4 showed that a game-based direct experience, inspired by the wisdom of crowds phenomenon [12,39], can increase the perception of social media influence on participants with statistically significant results if performances of the game are shown to students. The Wisdom of the crowd effect is expected if the correct aggregated estimate is shown to participants in line with the findings by Becker *et al.* [12], but due to social media influence, a biased aggregation of crowd estimate reduces the overall accuracy [11].

We conduct different statistical tests to check the effectiveness of our activity with promising results but also, several limitations. Firstly, the sample size is too small to generalize our findings. Secondly, the effectiveness of the activity in the medium and long term is still unclear. Lastly, participants' behaviour during the game and the magnitude of social media influence could be better investigated in relation with other scales such as the Fear of Missing Out (FOMO) [47,48] that has been linked to problematic social media use and negative health outcomes among adolescents. In the future, we plan to integrate the activity as a web tool for educators.

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Empirically Investigating Virtual Learning Companions to Enhance Social Media Literacy

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Abstract. Social media platforms provide opportunities for users across the world to connect and communicate between them and engage into acts of social support and entertainment. Yet it can also bring negative consequences as it has been associated with poor mental health and life dissatisfaction. This underlines the importance of delivering social media literacy (SML) interventions that raise awareness of the dangers and threats that are hidden within. To this date, SML initiatives have shown their benefits towards the acquisition of SML skills through the forms of school interventions and mini-games. However, studies on promoting SML through social media platforms need to be also encouraged and innovative approaches to provide interactive scenarios with hands-on experiences need to be formulated. Hence, the project COURAGE introduces a new approach towards SML by proposing the integration of educational opportunities within a controlled social media platform. To provide students the opportunity to learn whilst they naturally explore social media we propose the integration of virtual learning companions. In this paper we report seven empirical approaches towards SML skills acquisition powered by virtual learning companions. The paper concludes with a discussion towards the benefits and limitations of using this type of SML interventions.

Keywords: social media literacy · virtual learning companions · social media · empirical studies

1 Introduction

Social media are "computer-mediated communication channels that allow users to engage in social interaction with broad and narrow audiences in real time

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or asynchronously" [4, p. 472]. The most common social network sites such as Facebook, Instagram, Twitter, and TikTok provide these elements and thereby allow for bonding with others, disclosing the self, and getting social support [14,31,34]. However, aside from these positive aspects and experiences, the use of social media can bring negative consequences, as well. This is alarming as a large percentage of young users aged between 15 and 24 years use social networking sites [16]. Leaving them exposed to potentially harmful content in their everyday lives, even during school hours.

Harmful content can be related to body image, identity, or any other aspects which are important to young users, and can occur by means of toxic dynamics like cyberbullying, hate speech, fake news, or discrimination [32]. Consequences of being confronted and engaging with such negative dynamics can be related to somatic or depressive symptoms [21,58], emotional problems, poorer academic performances [54], or suicidal thoughts [59]. In addition to that, bullied individuals or those confronted with toxic content could evolve as bullies themselves, because they do not know how to protect themselves or get out of the situation otherwise. From a more technical perspective, algorithms as well as targeting processes can also be a threat to users' autonomy (e.g., [30]).

Although social media is not bad per se, and there are many other predictors for low well-being or depressive symptoms [12], these threats call for action in researchers to formulate innovative ways and develop educational tools to increase awareness in young users with respect to the panoply of harmful phenomena of social media [42]. In the long term the aim would be to increase users' self-protection skills, so that they can act completely autonomously and self-secure on social media.

Scholars have already investigated the role of social media literacy (SML) in the context of the secure use of social media [8,18,34]. Following Livingstone (2014, p. 286), SML includes and refers to "the tasks of decoding, evaluating and creating communication in relation to media qua representation (text, image, platform, device, etc.) and qua social interaction (relationships, networks, privacy, anonymity, etc.), since these are integrated in the very nature and use of social networking sites".

Interventions focusing on SML have so far demonstrated positive effects towards skills acquisition [20,41], leading the way to more technologically advanced approaches. One such approach is the implementation of web-browser plugins that act as virtual learning companions transferring information to users during content browsing [33]. Virtual learning companions usually take the form of chat-bots ready to support a user when in need without being intrusive. They can be deployed to accompany users through educational resources and provide further knowledge when requested.

We argue that SML supported by virtual learning companions can help to educate users to not only understand harmful content, but also the effects of the messages that one creates and distributes. This can serve as the key for creating and enhancing self-protection skills and guaranteeing autonomous and self-secure use of social media. In the COURAGE project we aim at inducing

SML and several self-protection skills (including e.g., raising awareness, emotional intelligence, empathy) within the environment of social media supported by a virtual learning companion [44,51]. This will provide users directly with support when needed, avoiding adoption problems. In this paper we report seven approaches towards SML skills acquisition powered by virtual learning companions, developed as part of the COURAGE project. A discussion is then made towards their potential benefits as potential educational tools.

2 Social Media Literacy Interventions

SML is a form of literacy that focuses on training skills for the growing digital environment. A "correct" (i.e., non-harmful) usage of social media is crucial to exploit all the advantages offered by the new media, especially for teenagers who need to be supported in order to cope with the different threats and drawbacks omnipresent in it. SML interventions have demonstrated to decrease social media addiction [25], and to be beneficial towards the acquisition of skills related to digital competences [41] and fake news discernment [20] amongst others. They can be integrated in school curriculum as specific subjects or integrated within each curricular discipline. Such interventions can guide students in analyzing social media messages by reflecting on the sources, the language used, and the reliability of images promoting and reinforcing other literacies (i.e., health, arts, citizenship) [7].

Current studies have developed different forms to deliver SML interventions. For instance, an initiative led by [55] designed a collection of activities for classroom instruction to combat misinformation in social media. On their part, [47] aimed to raise awareness of body image concerns, by designing an intervention manual which was beneficial in the format of six or three interactive lessons [13,41]. More recent interventions, such as the one conducted by [6] during the COVID pandemic found that online asynchronous assignments can help to improve fact-checking through a lateral reading course.

Implementation of more playful experiences, in the form of educational minigames, to raise awareness of fake news detection have also shown to improve participants' ability to spot misinformation [3]. Even more, the development of playful educational tools that are available to the public have shown to attract participants in large scales, specifically by the teacher's communities [19]. Which puts an effort in the design of tools that provide opportunities to educators to create lesson designs that adjust to their curriculum.

A common theme in the aforementioned studies is the creation of fictional use cases outside social media to raise awareness of potential threats and dangers. However, studies on promoting learning through social media need to be encouraged [11] and innovative approaches to provide interactive scenarios with hands-on experiences need to be formulated. Moreover, learning scenarios need to be designed without using censorship or restriction [48].

In this line, the introduction of initiatives to integrate educational opportunities within a controlled social media platform have been targeted as an opportunity. This integration would give the ability to educators to create educational materials attached to social media scenarios that would otherwise be difficult to be replicated in the classroom. To successfully achieve this, an educational component providing the resources to the students needs to be carefully designed to provide an engaging learning environment to the students and educate them towards a safer use of social media. This could be achieved with the implementation of a virtual learning companion (VLC).

3 Virtual Learning Companions

A VLC can be characterized as a companion that shares a learning experience with the student and takes the role of a knowledgeable peer rather than appearing as an expert in the subject domain [45]. It usually takes the form of a computer-simulated character who engages in conversations with the student through an interactive chat interface [10].

The use of VLCs in educational scenarios is not a novel approach and it has previously shown its benefits towards students' engagement and motivation [26]. Previous work has seen their successful implementation in the classroom in topics related to science [45] and mathematics [26]. Aside from cognitive skills acquisition, VLCs have also shown to be beneficial towards affective learning [56], and raising learning curiosity [57]. It is therefore evident that the use of VLCs in education can be beneficial across different domains. Work connecting the topic of SML and VLCs has seen the implementation of browser plugin digital companions, that provide individuals with tools to verify the credibility of digital content in social media [9] and support them in addressing misinformation through nudging mechanisms [33]. Moreover, VLCs can be traced to boosting [23], a particularly promising paradigm to increase online users' competencies and counteract the potential drawbacks of social media. Boosts focus on interventions as an approach to improve people's competence in making their own choices.

Further studies connecting diverse topics of SML and VLCs are scarcely available. With the aim to fill this gap in research, the COURAGE project proposes the use of VLCs towards the acquisition of SML skills. In particular, we are interested in investigating how VLCs can be used as part of SML interventions for the acquisition of diverse skills. Hence, seven empirical studies were designed each covering a different SML topic. In the following section, we present two different technical approaches of VLCs and then proceed to summarize seven diverse interventions that were designed. We then proceed to discuss the benefits and limitations of using this type of SML interventions.

4 The COURAGE Project and Its Contributions

4.1 COURAGE Browser Plugin

The first VLC was developed as a Chrome browser plugin to support users during social media content browsing. Once the user activates it, a chat-like interface appears on the right side of the webpage. Within the interface, a chatbot greets the users and guides them through learning material related to the content they interact with (see Fig. 1). During the interaction, the chatbot provokes users to reflect on content by asking questions, making suggestions and directing them to complete tasks to enhance their learning experience [2]. Initial work saw its implementation within a simulated social media environment that replicated Instagram (Pixelfed [39,52]). This environment allows participants to interact between them by posting, commenting and liking content. Due to the nature of this work the environment was slightly modified to allow the implementation of educational material. Nevertheless its integration is also possible in real social media platforms.

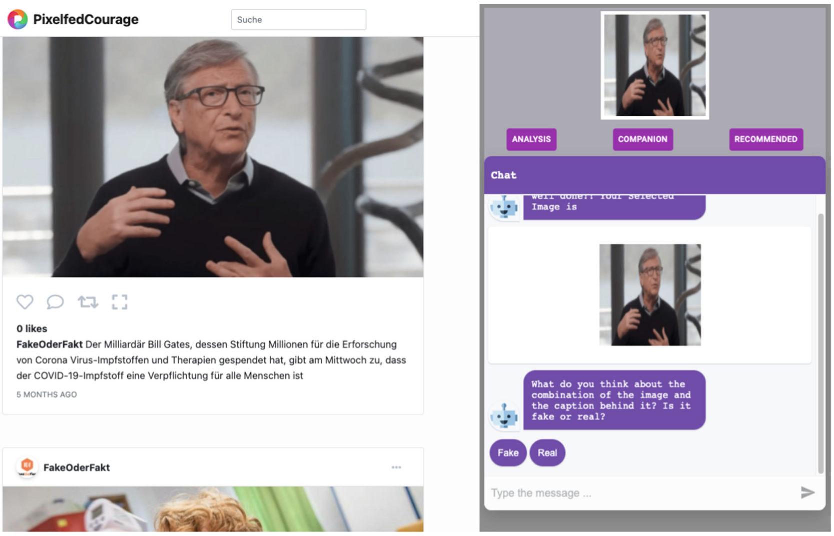

Fig. 1. The VLC interface. In this scenario, the student is able to interact with the companion and receive information related to images they have been seeing in their timeline.

To evaluate the browser plugin VLC, the following empirical studies have been conducted or are currently ongoing within our own controlled social media environment, addressing the topics of fake news and everyday racism.

Fake News. Studies have shown that users with higher media literacy are more likely to identify fake news [27,43], especially those with higher information literacy [28]. Therefore, interventions addressing the negative effects of fake news should focus on improving users' information literacy skills, among others. In a combined study to evaluate the practicality of the browser plugin VLC and its effect to support learners in judging the veracity of content, a preliminary study was designed with participants aged from 19 to 65 years [1]. During the intervention, the participants were presented with three images that contained a fake, fact, and controversial item regarding COVID-19. Participants were asked to express their opinion about each image and classify it as fake or fact. It was also possible to give a neutral judgment ("not sure"). The companion then presented the users with links to the same images in different contexts based on reverse image search. This was supposed to help the participants in identifying fake news and encouraged them to explore external tools and resources to identify manipulated images. On their return, the participants were asked to reclassify the images and justify their choices. Results show that participants' performance was improved after the interaction with the VLC. In a more recent study with the same environment and a larger user group, we could confirm that the agreement with experts ratings increased after the interaction with the VLC and that the judgments were more determined (less "not sure").

Everyday Racism. Since racism also operates in everyday situations, for instance through incidental expressions [15], interventions targeting this form of discrimination are necessary. Similar to the scenario described above, young users between the ages of 12 and 19 explored a closed social media environment, receiving information from the VLC on the topic of racism related to an ad containing racism. For realizing this use case, however, InstaCour was used, which was also developed by the COURAGE group and represents a closed social media environment. In contrast to Pixelfed, students here do not have the option of adding comments under the posted images or liking posts. We intentionally chose this approach to keep the environment, and thus the conditions, consistent and uniform for all students throughout this iteration. We hypothesize that students who receive information on the impact and background of such everyday racism examples by the VLC will be more critical regarding social media content and more aware and literate regarding racism. Also, we suppose that users who interacted with the VLC and got information on racism will score higher in a quiz after the interaction than before. For the purpose of this study a social media ad was added to the closed network promoting a pen in "skin color," prioritizing the interests of white people and thus reflecting white privilege and the dominance associated with it [40]. A full study design was developed, covering one experimental and one control group for testing the effects of the virtual learning companion, either transmitting information on racism (experimental group) or not (control group), on users' knowledge and awareness regarding racism (behavioral and informational) in social media environments.

4.2 The Narrative Scripts

The next iteration of the VLC saw the implementation of the Narrative Scripts which combine elements of storytelling, collaborative learning activities and mini games [22] within an educational social media platform (ESM). The introduction of those elements within this context provided a further opportunity to enhance the educational material that students would receive as part of the VLC interaction. The incorporation of storytelling provides educators the ability to design lessons that can unfold within a controlled SM environment and create social media scenarios that would otherwise be difficult and dangerous to be replicated in the real world. The coordination of collaborative activities within the environment provides an opportunity to students to share opinions about the topics between them through role playing. Finally, mini-games serve as small activities or challenges that provoke students to reinforce the learning they received. The incorporation of these three elements within the VLC under the narrative scripts are complemented by the use of counter-narratives that can trigger different learning scenarios based on the students behavior in the ESM [35]. The use of counter-narratives in the topic of social media can be used to expose students to scenarios that counter the content they consume everyday. To investigate the narrative scripts as an educational tool towards the acquisition of SML skills two interventions were designed to explore the topics of social media self-protection skills and cyberbullying.

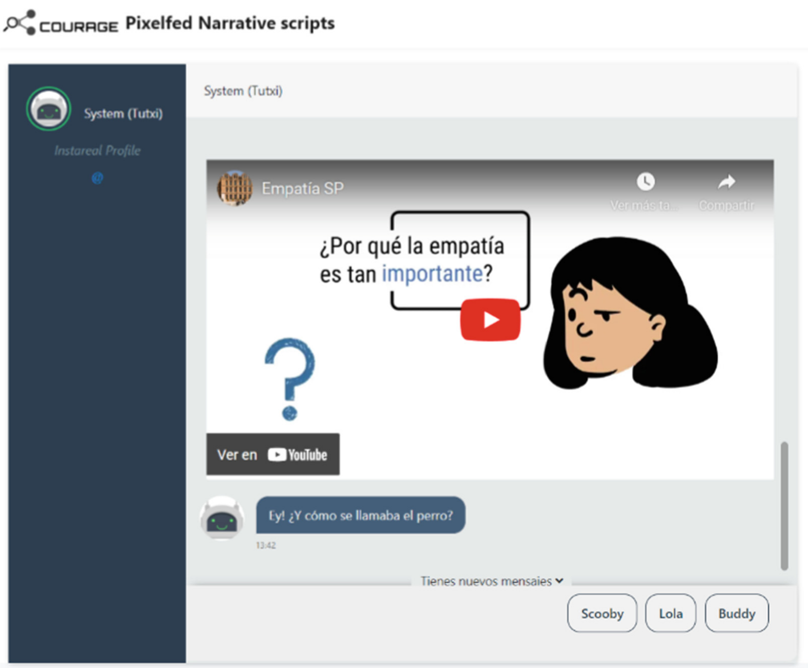

Fig. 2. The narrative scripts interface. The student follows a story that is enriched by interactive learning components such as videos and multiple choice answers.

Social Media Self-protection Skills (SMSPS). Whilst social media has its own sets of risks, adolescents might not avoid them as easily and may be less able to cope with difficult experiences. This could be due to key areas of the brain controlling decision making, self-awareness, and understanding of others not being fully developed. Consequently, putting them in greater risk of developing mental disorders [29]. Thus, we proposed the development of an intervention with the aim to teach adolescents how to cope with difficult experiences they might come across in social media. For this, an educational intervention was designed to evaluate the use of the narrative scripts to enhance adolescents' SMSPS in the age range of 14 to 19. This intervention saw the design of six 2-hour sessions covering learning material related to the topic of digital self. During each session students followed the stories of four fictional teenagers and their experiences in social media through the VLC complemented by mini-games, collaborative activities, media (videos, images, voice etc.) and guided roaming. The stories covered different social media scenarios in topics such as wellbeing, reputations, social media and our brain, body image and AI algorithms.

Empathy Training. A second educational intervention proposes the design of a narrative script to sensitize adolescents to the negative effects of cyberbullying. We hypothesize that students who participate in the empathy training will show higher levels of perspective taking, higher intentions to help victims of cyberbullying, and lower intentions to reinforce bullies online, for example, compared to youth who do not participate in the empathy training. For this training, two videos were created in German and Spanish, containing examples and definitions of empathy and social media, respectively (see Fig. 2). In addition, two memes (i.e., an image enhanced with text) depicting bullying scenarios were created on which one of the authors is only partially visible. During the study, students will watch either the empathy video (experimental group) or the video about social media use (control group). In both conditions, the image is embedded as a posting in our own closed and controlled social media environment. Thereby, the students are guided by a virtual companion, either by being invited to empathize with the victims (experimental group) or by answering simply decoy questions regarding the social media video (control group). We plan to conduct the study with 12–15 year olds in Germany and Spain. In total, the completion of the pre and post questionnaires and the interaction with the virtual companion will take about 45 min.

4.3 Future Features Studies

In future studies, the VLC will be enriched with additional educational material and computing mechanisms aiming at further promoting and enhancing students' SML skills. An initial step has been done in terms of evaluating the material and activities in schools (supported by teachers). Additionally, computing mechanisms have been explored as tools to further support students' SML skills.

Emotional Intelligence and Fake News. Emotional Intelligence (EI) is described as the ability to identify and manage emotions, reason, decision making and problem solving. A recent study has shown that people with a high level of "EI" have fewer probabilities to be attracted by fake news thus showing a more conscious use of social media [46]. Therefore, to promote a more conscious use of social media, this study designed an educational intervention towards the acquisition and reinforcement of EI skills. In particular, it aimed to investigate the ability of adolescents to discern real or fake news in social media in relation to the levels of EI and verify the effect of an educational intervention to increase EI in adolescents. This study was aimed at adolescents aged from 16 to 19. Students were trained for ten 2-hour sessions in the following topics: awareness of emotions, empathy, assertiveness, interpersonal relationships, anger and impulse control, adaptability, problem solving, stress management, conflict management, and optimism. This study was conducted outside the VLC environment however a future implementation could foresee its adaptation in the VLC.

Image Manipulation and Unrealistic Beauty Standards. Social media can contribute to the normalization and trivialization of unrealistic and unhealthy beauty standards [24]. Being confronted with idealized and edited images of others can lead to a negative body image, driven by upward comparison processes [17] and may foster extreme impression management activities, again. Thus, it is critical for social media platforms to be transparent on the level of image editing that an image goes through. To enrich the VLC towards this matter, an image labeling feature was investigated towards its feasibility to be implemented as part of the ESM platform. The image labeling tool saw the tagging of images based on their level of alteration. An initial study examined how adolescents understood and accepted this approach [49]. For this, a mini game was developed exposing students to two different editions of a photo with descriptions underneath of the level of alteration in each. Students were then asked to select which image they prefer. After the mini game the students were asked to evaluate the feature. Findings have shown that image labeling can help to decrease affinity for edited images. Therefore, a future iteration would see the implementation of this tool within the VLCs.

Social Media Influence and Echo Chambers. Finally, there is an importance to provide students with appropriate training to understand and deal with social media computing mechanisms and their possible drawbacks. Specifically students' awareness of algorithm-based personalization of information, filter bubbles and the resulting social counterpart, echo-chambers, is crucial. An understanding of these computing mechanics would give students the basic skills and knowledge for recognizing and evaluating the impact of new technology in different situations and contexts [53]. Thus, an educational activity inspired by the "wisdom of the crowd" [38] theory was developed to raise awareness about the effects of social media influence and information personalization [5,38]. The main objective of this work was to allow students to reflect on the effect of personalizing information to increase the awareness about the influence of social media. During the activity students received a talk related to the impact and differences of traditional and social media on user attitudes, beliefs and opinions [37]. The talk also covered topics related to personalisation algorithms highlighting the concepts of echo chambers and filter bubbles. Finally students were exposed to a "wisdom of the crowd" experience consisting in a social perceptual decision task, i.e. each user had to estimate how many dots were present in an image. In this experience the presence and bias direction of the social influence was manipulated by presenting aggregate estimations of all the participant choices that could be exact or biased, as only a polarized subset of users was selected. Presentation of biased estimates resulted in higher estimation errors. The students were later presented their performance and explained the presence of the two different conditions, exact and biased, as well as the parallel between the biased condition and the social media echo-chambers.

5 Discussion

For most children and adolescents in the western world, social media adds a level of socialization. Youngsters interact within the social media sphere not only with the purpose to meet informational demands but also to construct citizenship. Compared to former generations, youth is fully oriented to digitalization as the material supports shaping their values and identity. Following Livingstone (2004), if it is true that teens spend an unbalanced time of active and passive communication, teens' social media investment cannot be reduced to leisure and entertainment nor to the stigmatized image of "the media-controlling children". Teens' social media time is embedded in other socialization practices such as education, collaboration, and information-seeking [50]. Although banning access or restricting the time to social media seems to be a more efficient solution, prohibition will not cover the cost of lacking literacy. Providing social media situated scenarios such as learning about social media with social media might be an opportunity to grant access and security to young users. Just as people learn how to drive a car with a theoretical course and teacher-guided practice, training with tools such as VLCs can grant youngsters to safely navigate in virtual environments.

The VLCs developed as part of the COURAGE project may offer teachers, learners and families an enriching educational approach to social media. As part of the benefits observed in the different interventions, three opportunities have been listed to support the implementation of COURAGE VLCs for SML:

- *Multiliteracy approach:* VLCs can cover different areas of knowledge and topics. Although the tools have been designed to equip users with knowledge and competencies regarding the (mis)use and effects of information and technology, acquiring such competencies has an impact in other domain areas such as mental health and well-being. In line with scholars such as [7] and [50], COURAGE VLCs attempt to stimulate critical thinking from contextualized experiences. SML is produced as an outcome of the critical interpretation of scenarios where users access, use and apply information for daily living.

- *Autonomy and self-guiding:* VCLs have the potential to be deployed in school training without support from the developers in the form of educational tools. This facilitates its incorporation into formal school curricula or by external trainers (i.e., parents/tutors). Moreover, VLCs design makes users' experience intuitive rather than instructional. The interactive experience, for instance with chatbots in narrative scripts, makes learning a gamifying experience. Consistent with self-determination theory, VLCs as a participatory support system also protect youth autonomy since the VLCs create choices instead of censoring content.
- *Be Adaptive for learners:* Similar to traditional social media platforms, VLCs can be automatized and supported by AI Algorithms. The benefits of implementing systems such as xAPI can guarantee tailored experiences for users to reinforce their learning dynamics.

However, the development and implementation of VLCs have their own set of critical points. To begin with, the replication of a social media platform and/or social media features may conduct users' into more individual actions such as posting, liking, or sharing rather than interactive or collaborative practices. This could potentially become a threat to the learning aims of the material. It is therefore crucial that VLCs provide monitoring tools to administer the content and supervise online behavior. This leads to a more important discussion concerning the ethical issues and implications that the combination of social media platforms and educational tools might have (e.g., addressing young people whose identities are still developing, using potentially biased algorithms, deciding which behavior is acceptable and which not). This topic is addressed in more detail in [51].

Another important aspect to mention is the fact that social media is an environment constantly changing. The implementation of interventions for today's popular media such as Instagram and TikTok may soon be outdated. The design of educational tools such as the VLCs may need to be updated accordingly to newer applications and youngsters' interests.

Finally, despite the growing number of families and educators adept at technology and SML, others keep a restrictive approach toward social media. Some of the tools introduced in this paper were partially tested in schools (experiments finished earlier) as parents or teachers did not trust this SML approach considering the introduction of digital media and VLCs more inductive than reductive for social media use. Not until digital literacy would be considered part of children's education, implementing VLCs (at least in schools) might be more complicated. Research evidence is, therefore, necessary to debate both the positive and negative outcomes of teaching with technology.

6 Conclusion

There is an immediate need for SML initiatives to educate about social media dangers through innovative educational methods. Hence, this paper introduced seven empirical studies that have been developed as part of SML interventions with the support of a VLC. Each study proposed a diverse solution covering different aspects of social media threats and dangers. Studies that have been conducted so far as part of this project have shown a positive impact of the VLC. In the case of the narrative scripts adolescents had a positive interaction with the educational activities generating intrinsic motivation [36]. Moreover, students using the browser plugin to reflect on fake news veracity have shown more deterministic judgments after interacting with the VLC [1]. Finally, students engaging with a scenario powered by machine learning mechanisms have shown an increase in their understanding of how such algorithms work [37]. With a few more studies currently in the line to form our final judgment, we believe this work has paved the way for future research combining these two fields.

However, we believe that SML interventions cannot be taken as the only solution to all the problems surrounding the world of social media. It is also necessary to encourage teachers, parents and caregivers to participate in training to support schools with regard to knowledge and awareness about SML. Overarching interventions are needed to cover users' social cultural backgrounds.

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Concept of Quality in Online Environments: The Actual Role of Teaching and Learning Centers

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Abstract. The last two years have been characterized by important and rapid changes in teaching models and strategies, given the repercussions from the Covid-19 pandemic on world societies. In such a scenario, according to the research needs that have emerged, EDUCAUSE has developed a specific survey relating to the new challenges of higher education. Last year, its research team drafted and presented the Horizon report, with the subtitle, *Teaching and Learning Edition.* Among its various topics, quality online learning is analyzed, since one of the emerging challenges that higher education finds itself facing is involving all stakeholders of academic institutions in the quality assurance processes.

The present study therefore develops an exploratory survey for the identification and comparison of good practices and development models of Teaching and Learning Centers (TLCs), with reference to online learning environments and digital skills of the teacher. It has in fact been noted that, among the projects recently triggered with respect to quality online learning, many of these have concerned the setting up of TLCs online. Consequently, in the second part of the article, some reference models about TLCs will be examined, developing a critical description of them, highlighting the strategies, tools and services involved.

Keywords: Teaching and Learning Centers · Quality online learning · Higher education

1 Introduction

The past two years have been characterized by sudden changes in higher education due to the adaptation of educational models to the new condition of distance learning. The year 2020 will indeed not only be remembered for the global and multilevel crisis that Covid-19 caused, but also for the sudden paradigm shift in education and training models. The advancing pandemic has progressively resulted in a complete closure of educational and academic institutions in every part of the planet [1]. Face-to-face education was quickly

Sector 1 is by Marco di Furia, sector 2 is by Pierpaolo Limone, sector 3 is by Marco di Furia and Guendalina Peconio; conclusions are written by Alberto Fornasari. In addition, Pierpaolo Limone and Alberto Fornasari supervised the full paper.

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replaced by online education, going on to define a true “emergency remote education” [2].

This emergency, in the field of education, has in fact affected more than 1.5 billion students worldwide, which is about the 91 percent of the whole student population [3, 4].

Therefore, current studies in the literature have shown a necessary change of attitude in almost all academic governance. For the first time many policy-makers have realized that the stakeholders within the teaching and learning processes should be more involved at both the design and delivery stages [5]. Quality assurance continues to be one of the main forces for achieving success within the organization: in addition to design, a management system that aims to meet the required quality standards is fundamental [6]. All of this has represented and keeps representing a challenge that includes different perspectives.

The main players within this shift in perspective turn out to be technological innovation, characterized by flexible learning environments, and the teaching strategies to be proposed within the new online or hybrid learning spaces.

In this regard, EDUCAUSE has prepared, in its latest report, an analysis regarding the new scenarios of higher education. EDUCAUSE is a global nonprofit organization whose members include international higher education institutions, corporations, other nonprofit organizations and K-12 institutions. In this panorama, EDUCAUSE has drafted and presented the Horizon 2021 report entitled “Teaching and Learning Edition”, whose purpose is to analyze the effects of the pandemic with respect to teaching and learning processes and proposing post-pandemic scenarios with respect to the world of higher education. The topics identified within the report are the following:

1. Artificial Intelligence (AI);
2. Blended and Hybrid Course Models;
3. Learning Analytics;
4. Microcredentialing;
5. Open Educational Resources (OER);
6. Quality Online Learning.

In the present lunge, Quality Online Learning (QOL) is placed under analysis, as one of the emerging challenges, in higher education, appears to be precisely the ability of academic institutions to involve all stakeholders within Quality Assurance processes [5]. The perceived quality of online learning technology users has been identified as a critical determinant of online learning effectiveness [7].

In particular, the Horizon 2021 report devoted attention to quality online learning, going on to describe and decline some of the technologies and practices that experts believe will have a significant impact in Higher Education learning and teaching [8]. It can be noticed that the number of projects submitted in the “Quality Online Learning” category is impressive: 63 projects submitted compared to a category that, until the previous report, did not exist. The explanation, associated with the need for quality assurance of online learning, primarily refers to the pandemic experience; a key aspect is the creativity, together with ingenuity and resourcefulness through which the projects were planned and implemented. Already Karim [9] predicted that the demand for online modality in Higher Education would grow internationally by 2025, predicting an increase in student users of about 163 million within the next 25 years. Considering the latest developments regarding the Covid-19 pandemic, it can be argued that this prediction has changed by far, because of the massive and cross-cutting use of the most up-to-date platforms dedicated to distance and blended education.

2 The Concept of Quality in Higher Education and Its Link to Motivation

In order for us to assess the quality that the effects and perspectives of the new teaching practices have, it is necessary to go to define the very idea conjoined with this paradigm. The term “quality” refers to a multidimensional concept involving different declinations. In academia it can refer to the different fundamental elements that define processes and outcomes.

We speak of “quality” in different processes: in teaching, in learning, and in delivery and evaluation processes. The concept “quality” is a real process that is controlled and monitored considering specific standards and performance parameters. Its purpose is for the organization to take care of the stakeholders involved and for students, faculty and technical staff to experience a participatory and transparent environment in the teaching and learning context [10]. In order to achieve these outcomes, quality assessment, in higher education, has always been governed by efforts aimed at achieving two topics: improvement and accountability. Tadesse et al. [11] point out a paradox arising from optimized efforts to achieve these two goals and link it to the concept of motivation.

In this direction, a prominent theory is the Self-Efficacy Theory by Bandura [12]. Through the concept of ‘self-efficacy’, reference is made to the perceptions that each individual has of his or her own ability (or otherwise) to perform an action and achieve a certain result. Dörnyei [13] emphasizes how this perception of self-efficacy influences the three dimensions of motivation: the choice of activities, the effort employed and persistence. It is possible to reason that such dynamics, present in every life context, are particularly incisive in the academic context. The dimensions of choice, commitment and persistence play a leading role in learning pathways, starting with the choice of the course of study, and then considering commitment to examinations and the relative persistence in achieving the goal. These characteristics, identified by Dörnyei [13], underline some of the fundamental aspects of students’ intrinsic motivation.

One substantial aspect is characterized by self-esteem. Deci and Ryan [14] in Self Determination Theory (SDT) highlight the importance of intrinsic motivation. The authors point out that when we are driven to make choices, intrinsic motivation is reduced and a sense of external control is perceived. They also emphasize that by supporting the development of autonomy, good levels of intrinsic motivation can be achieved [15]. Such motivation is indispensable in the success of the academic journey and, therefore, in the human and professional training of students.

In this perspective, a fundamental role is assumed by the social environment of reference; this can encourage the development of self-determination, through three psychological channels: skills, autonomy and relationships [16]. Thus, the key role of parents and teachers emerges: through good practices and relationships, they can promote the consolidation of intrinsic motivation [17].

Ryan and Deci [15] also point out that extrinsic motivation intensifies during growth, when the individual tends to make choices according to social demands. At the school level, intrinsic motivation decreases as school grades progress; that is, the older students grow, the less they tend to manifest their intrinsic motivation. By virtue of this, it would seem useful to promote the consolidation of practices aimed at the development and consolidation of intrinsic motivation, especially in more advanced academic environments, i.e. in higher and university education.

To promote internal motivation in students, it is crucial to start from the source: teachers. In the report European standards and guidelines for internal quality assurance within higher education institutions (2007), it emerges the need, starting with academic institutions, to ensure that teachers are given the opportunity to improve their teaching skills. This would lead to an increase in the quality of performance in teachers, students and the related academic reality. In line with the ENQA, the High Level Group on the Modernization of Higher Education, in its report for the European Commission on Improving the quality of teaching and learning in Europe's higher education institutions (2013), also emphasizes the importance of focusing on the quality of learning and teaching. The latter, in fact, should guarantee students up-to-date knowledge and skills in order to ensure their expendability within the labor market and society. The role of teachers is central to making young people active agents of change, with a view to individual life and active citizenship. To achieve this goal, it is therefore necessary to start with the trainers of the new generations, since they are the real promoters of change. Consider that training activities for academic teachers have an effective impact both on students, through an improvement in learning outcomes, and on teachers, through the development of professional identity and motivation to grow and acquire skills [18].

Tadesse et al. [11] identify a parallelism between the elements of improvement and accountability with, respectively, the concept of intrinsic and extrinsic motivation. Specifically, the authors conjoin the concept of quality improvement, derived from commitment through practicality [19], with the concept of accountability: driven by extrinsic motivation, closely related, to compliance with external quality or fund assurance requirements.

The paradox lies in the fact that the accountability principle requires adjustment to certain external quality standards and its goal is to appear as compliant as possible, regardless of actual performance. Differently, the improvement principle has different goals: it starts from poor performance to identify the problem and undertake reflections and actions to remedy and promote real enhancement of the situation itself [20]. Conducting an improvement – or accountability- driven quality assessment, therefore, involves very different approaches to each other. The former will be characterized by a bottom-up approach that starts with the protagonists of academic education: students, faculty, and technical administrative staff; accountability-driven quality assessment, on the other hand, involves a top-down approach marked by quantitative, externally declined measures intended for public communication. A good quality assessment should consider external quality standards while not neglecting internal ones, that is, those derived from the elements, on a daily basis, present and active in the institutions of reference.

Improvement and accountability are two concepts that should proceed in the same direction, starting with the needs found in the organization's internal stakeholders, but taking into consideration the quality standards that qualified agencies have developed and experienced. The purpose of Quality Assurance is to communicate, both internally and externally, that the academic organization, throughout its community, cares for each member: students, faculty and technical administrative staff. For such a system to be effective, it should also ensure that the academic environment is characterized by trust, participation and transparency in all computed areas [5]. The Quality Assurance system has undergone a major shake-up and rethinking in the face of the Covid19 pandemic. The entire mechanism of quality delivery and assessment, in higher education, underwent a series of abrupt changes due to a transformation of the modus operandi of the delivery and fruition of academic education, hitherto experienced by most universities in a face-to-face manner [21].

Universities, teachers, and students were unprepared for the sudden shift to learning and teaching in a full online form, but the stakeholders involved tried to identify new strategies to adapt and cope with the new challenges. Specifically, Coman et al. [22], in a study about students' perceptions of how universities were able to deliver knowledge in the context of exclusively online learning, identified some of the main strengths and weaknesses. It emerged how, at the beginning of the pandemic, universities did not possess the technical capacity to provide optimal conditions for online learning and there were a few technical issues; these difficulties also generated stress in students as they were not aware of the ways to implement to access reference classes [23]. Another emerging aspect is the lack of technical competence on the part of teachers: they failed to adapt in a short time their teaching style or to interact with students in online learning environments, ensuring high standards of the teaching process [24].

Lack of competence with respect to the online teaching mode has, in addition, led to consequences in terms of the proper use of time: students involved in the study did state that stated timings were not adhered to and that teachers did not take breaks. Students also stressed the perception that they had less free time available and that this resulted in negative impacts on academic performance. The quality of the educational and instructional process in the online environment depends on multiple factors among which emerge: faculty training in the use of technologies, teaching style, instructional strategies, ways of interacting with students, feedback, promotion of active learning, timing of assignments, and support for student motivation [25, 26].

At the point when these elements are lacking, during the teaching process, several risk factors emerge: students are found to be poorly focused due to the lack of effective strategies, during learning, online in the teachers' skill set; further problematic is that related to domestic sources of disruption: students have found a lack of adequate space for learning and this affects the amount of time students invest in concentration for online learning [27]. However, for the educational system to adapt to online teaching and learning, a number of actions need to be taken that can stimulate and facilitate its adaptation properly and successfully to this new type of teaching. In this regard, universities could develop training sessions for teachers or could develop programs whose role would be to stimulate teachers' performance and implicitly the quality of the educational process [28]. Indeed, research has pointed out that in online learning environments, students and teachers play a reciprocal role in each other's experiences [29]. In fact, when teachers present better teaching performance, their respective students render to have higher satisfaction. This reason lies in the mode of teaching that can impact students' motivation and degree of involvement in learning dynamics [7]. Technology is only a tool, and the teacher's instructional implementation of online learning technology can largely influence the effectiveness of learning [30].

The teacher's competence in the use of technology is therefore critical to ensuring effective online learning experiences in students. Teaching is indeed a professional practice strongly underpinned by intrinsic motivation, which can falter under certain conditions. When we speak of teaching motivation, we are not only referring to the teaching class itself, but to all the recipients of the teaching practice: from the students to the society around us. Bess [31] emphasizes that it is difficult to consider teaching a profession, as it is a practice that requires a strong intrinsic motivation. Dörnyei and Ushioda [32] identify five risk factors for teachers' motivation: stress related to the teaching profession, low autonomy, low degree of self-efficacy, difficulty in keeping up the degree of intellectual involvement, and the absence of career paths in teaching.

Martyushev et al., in a 2015 study [33], describe a prize-based methodology to consolidate teacher motivation: the authors' reflection starts from the difficulty of reconciling teaching and research activities. In this regard, a point system was developed that considers: active research activities, publication of articles, conferences and projects. The teacher's rating is thus characterized by scientific work. All this is a function of the subsequent distribution of the teaching load; in fact, at the end of the term, the score is transferred to the teaching load: teachers with the highest score obtain a lower teaching load than their colleague with the lowest score. In addition to this 'points' modality, another interesting aspect concerns the rewards that can be received on the basis of students' achievements. In fact, based on the successes achieved in the training of students participating in research activities, lecturers can receive: gifts, bonuses, letters of recognition. All this is aimed at consolidating good motivation in the profession and teaching practices.

Alexander [34], on the other hand, focuses on preparation courses for future teachers, pointing out that such programs mainly focus on notions and content. In contrast, didactic, meta-cognitive and classroom group management skills feature little in these courses. Studies suggest that mastery-oriented practices and classroom management techniques play a key role in promoting students' intrinsic motivation [35]. There is a clear need for interdisciplinary and meta-cognitive programming that helps teachers immerse themselves in the complexity of the role. Another study [36], analyzing a sample of 1252 teachers, highlights how poor psycho-pedagogical skills have a double outcome: low self-efficacy in the educational relationship with pupils and the development of a sense of job dissatisfaction.

3 Models of Teaching and Learning Centers (TLCs) in Online Learning: Current and Developing Good Practices

It has been pointed out that one of the fundamental means capable of promoting effective learning in students is ongoing teacher training. There has been a real transformation in education over the past two years: all over the world, educational and academic institutions have been called upon to reinvent their teaching and bureaucratic organization to cope with the educational emergency that the pandemic has initiated. Williamson et al. [2] called it an "emergency remote education" as many of the aforementioned institutions faced the transition from face-to-face to distance education for the very first time. Against this backdrop, it was reflected how higher education has responded. The response was timely, but the results were directed in different directions: on the one hand, there was the consolidation of those online teaching practices that some universities had already put in place; on the other hand, there were those institutions where teaching practice had always been traditionally face-to-face in nature. In this view, we reflected about the role of the motivation in learning environments.

As mentioned above, motivation to learn is a process that starts from within the individual: it activates, directs and supports the learner in the conscious acquisition of skills, knowledge and attitudes. Motivation provides insight into why an individual performs a task in a particular way, how persistent he or she is in completing it and why he or she maintains interest in achieving the goal.

At this particular time in history, emerging technologies are present in every sphere of life and are having a profound effect on public education. Benešová and Tupa [38] point out that only qualified, trained and educated people can effectively control new technologies. Lifelong education and training therefore play a significant role in dealing with today's technological revolution. These two aspects, in fact, are active promoters of change. Moreover, such change stimulates the development of cognitive, affective and psychomotor domains; when there are learning activities that aim at the development of new educational paradigms, there is an enhancement of the aforementioned areas [39]. Technological tools, in learning processes, help learners to develop autonomy. Learners can access innumerable content by means of the many available platforms and it has been found that teaching, by means of information technology, motivates students to learn and optimizes the classroom environment [40]. It is therefore interesting to investigate the studies on students' motivation and self-efficacy in relation to blended and online learning. Analyzing the relevant literature, various insights on the correlation between motivation and blended and online learning come to attention. When learning in this modality, students need a structured experience because they do not build direct interactions with teachers; motivation therefore plays a key role in successful learning. Abrami et al. [41] highlight the need to design online learning and blended learning paths aimed at promoting: student motivation, student-student interaction, individual self-regulated behavior. This requires researchers and teachers to rely on evidence-based instructional design principles. In this regard, Bernard and colleagues in their 2014 meta-analysis identify three main areas of work: self-regulation design principles [42]; motivational design [43]; and collaborative and cooperative learning [44].

A number of researchers [45–48] have emphasized the pivotal role of conceptual, meta-cognitive and strategic scaffolding embedded in CbLEs (Computer-based Learning Environments) because when students study in the absence of scaffolding, they show poor capacity in the regulation of their learning and therefore do not acquire adequate understanding [49, 50].

Another component which interacts with the motivational process, is the emotional component. Already in the European Commission's Horizon 2020 ICT program, the importance of making e-learning an emotionally aware form of education in the future is emphasized. Nassr et al. [51] point out that, in face-to-face learning, teachers are able to perceive students' emotions and modulate themselves accordingly. Students' motivation, therefore, passes through this dynamic. In virtual learning, on the other hand, this cannot happen and it is therefore essential to find ways that can act as a stimulus to student motivation. The authors identify the importance of structuring 'intelligent' virtual learning environments (VLEs) capable of recognizing emotions, understanding them and reacting accordingly. It turns out, in fact, that students are motivated to use a VLE when teachers are able to understand their emotions.

One tool of digital learning environments is the MOOC (massive open online course). Huang and Hew [52] found a paucity of literature on assessing the level of student motivation in MOOCs. They therefore developed a research study to assess the level of motivation. From the analysis, they found that one component that motivates students not to drop out of a course is receiving feedback during the coursework. But there is a risk factor related to attention: not being able to maintain a high level of attention could inhibit students from completing the task. Furthermore, during the evaluation, it turned out that the group of students who had completed the course was more motivated than the group of students who had interrupted the course; this confirms the hypothesis that a good level of motivation may be predictive of course completion.

Within this overview, the question was raised as to how these institutions reacted to the change and, above all, what was the model used to cope with the new requirements. Schlesselman [33] pointed out that one of the models employed to cope with the educational emergency was characterized by putting in place Faculty Development initiatives and proceeding through the establishment and use of Online Teaching and Learning Centers (TLCs). The quality of the teaching and educational arrangements prepared by the institution is, in fact, a crucial component of the studentcentered approach. Institutional practices related to Faculty Development have placed a focus on new paradigms related to learning and assessment, evolving in practices and organization [53]. At the core there is the changing professional epistemology of faculty acting in higher education. University lecturers become true agents of change with respect to the context of reference [54].

Essential tools in this evolution are Teaching and Learning Centers, or centers designed to promote excellence in teaching and learning processes. TLCs aim to promote forms of apprenticeship and transmission of best practices between senior and junior faculty, aiming, in addition, to facilitate research perspectives through the sharing, among faculty, of problems, analyses and formative solutions [55]. The development of teachers' teaching skills, in academic education, is strongly connected with the production of quality teaching, apt to form students characterized by problem solving, critical thinking and meta-cognition skills. Moreover, in higher education contexts, it is crucial to collaborate with faculty colleagues to design and monitor united by the goal of sharing innovative projects useful for the improvement of teaching and professional practice

[56]. Some university institutions, therefore, found it necessary to invest in upgrading to ensure a professional development opportunity that, through ad hoc training on high-quality instructional expertise, could meet the new challenges.

In TLCs around the world, during the pandemic phase, instructional designers therefore spent the very first months reinventing the instructional delivery system and training faculty, administrative technical staff and students in teaching and learning processes. That happened thanks to individual interviews, collective trainings, and video tutorials with the aim of delivering training that could meet the needs for progression and updating of teaching practices [33]. In some contexts, it was first and foremost to go and define what was and what was not online learning. As Cook [57] points out, online learning refers to learning that is enacted while engaged in online activities specifically designed to achieve specific learning objectives. This can be accomplished in a variety of ways, including the presentation of learning materials, communication systems that facilitate learning-centered discussions, and activities that enable practice with authentic scenarios i.e., simulated environments. At the same time, it was necessary to clarify what online learning was not i.e., the undesigned online publication of course information (syllabi or handouts), archives of lectures (e.g., PowerPoint slides or videotaped lectures), online administration of tests and course evaluations, and administrative communications. At the same time, however, it has been pointed out that these latter elements, even if they do not produce, in a direct way, online learning, constitute usable and useful elements in the promotion of an online learning course.

The Horizon 2021 report highlights some of the good practices that, over the past two years, have been delivered with respect to the area of "Quality Online Learning." Specifically, there were a total of 63 projects pertaining to this category. The number is incredibly surprising when one points out the fact that this category, until the previous report, did not exist. The explanation associated with the need for quality assurance of online learning primarily refers to the pandemic events experienced; a key aspect that emerges is the creativity, ingenuity and resourcefulness through which the projects were planned and implemented.

Several institutions have rethought pedagogical-didactic practice through the creation of centers and hubs, finely created to meet academic needs through the organization of instructional technologies aligned with evidence-based learning theories, teaching and learning strategies.

In this chain of projects presented and well declined and disseminated through the Horizon 2021 report, a common modality emerges namely the use of digital platforms and purpose-built sites that, however, develop two main thematic areas:

- Teaching and Learning Centers Online.
- Digital platforms aimed at laboratory learning.

Dwelling on the first thematic area, a virtuous example refers to the experience of Indiana University: an online Teaching and Learning Center organized in two separate portals. Keep Teaching aimed at teachers and Keep Learning aimed at students. Both sites are curated by academic and technical experts and have as their mission to provide useful tools for teaching and learning.

The Keep Teaching is built to promote self-directed learning with a view to design, delivery and evaluation in online education: it offers tools, strategies of a theoretical practical nature, video-tutorials and direct contacts of Teaching Learning Centers and E-learning Centers, for in-depth information.

Specifically, Keep Teaching [58] is organized into 4 macro areas:

- Get Started: a set of suggestions designed to plan the content and mode of delivery of the teaching course. It offers hints related to content organization, lesson creation, student encouragement, and learning assessment. The purpose of this unit seems to be to provide suggestions for those new to innovative teaching methodologies and new digital technologies.
- Strategies: proposals for strategies to promote: content creation and distribution (canvas at the center, creating lessons and video content, curating and delivering others' content, encouraging reading and viewing of material); assignments and feedback (using canvas assignments, adding digital learning materials to the course, recording attendance, monitoring and feedback on student engagement, designing peer review assignments); communicating and facilitating activities (coping with the new learning environment, communicating and listening to students, facilitating communication, adhering to office hours, creating and maintaining a sense of community, adapting the face-to-face teaching style in a hybrid or online environment, engaging students in a Zoom class session, using think-pair-share in online or hybrid environments, facilitating group work using Canvas, performing lab activities); assessing learning (considering alternative assessments, assigning papers and projects including group assignments, using Canvas to collect all student work).
- Tools & resources: this section refers to guides for using technology in the classroom to continue teaching students in a blended mode (Keep Teaching in the Classroom); general information and guidelines aimed at effective online learning (Keep Teaching Resources); instructions on how to use specific tools in digital learning environments (Keep Teaching Tools).
- Find help: references about pedagogical and educational technology advice available to teachers and tutors. In particular, this area of the site is declined through the contacts of two main types of centers namely the various Teaching Centers aimed at support in view of innovative strategies and the Help Centers deputed to solve technical issues.

Keep Learning has placed its focus on three main aspects: academic success, being in relationship with peers and teachers in the learning context, and individual mental and physical well-being. In fact, useful tools have been provided for students to promote and support all the dimensions mentioned. Keep Learning is characterized by useful strategies for learning, concrete tools and initiatives to keep exchanges and relationships firm, and practical suggestions (including through the promotion of specific applications) to the monitoring and promotion of well-being. The interesting aspect of the Indiana University initiative is the cross-sectoral participation, in organizing and proposing contributions, by all active stakeholders in the academic community: faculty, students and staff have indeed provided useful ideas and tools.

In particular, the Keep Learning [59] portal is characterized by four different thematic areas:

- Technology: characterized by "useful technology to connect you." This lunge features a series of suggestions designed to enhance the ability to interact with fellow students and faculty to promote effective learning. In particular, digital tools useful for academic success are highlighted. This section refers to the technical apparatus, also suggesting useful supports for students with special educational needs.
- Staying connected: here are a number of useful suggestions for maintaining real but virtual contact with colleagues and faculty. This section was created in conjunction with the pandemic to promote and ensure constant social exchanges and address the isolation issue arising from learning exclusively online. In fact, a number of initiatives were put in place at this juncture: one of which "Quarantine Buddy" allowed people to "take a quarantine buddy" and experience the delicate period of distance together. In addition, useful information was also provided to support meaningful exchanges with teachers and tutors to ensure good learning.
- Self care: suggestions deputed to self care and mental health were provided. First, key points were identified in the Keep Learning section of the website to be dissected to provide useful support for the pandemic phase. Good practices reconnected to aspects of diet, sports activity, stress, rest, low mood have been highlighted, and useful apps and software have also been suggested for self-monitoring of what is explicated in the guidelines.
- Your campus resources: here are collected all the useful references to support the student for all his or her needs: from technological support to academic support, passing through the centers devoted to special educational needs and health and wellness.

Further initiative highlighted is the Online Engagement and Teaching Hub at Western Sydney University [60]. Like Indiana University, the online hub features several sections that provide opportunities for in-depth study with respect to the technologies, challenges and case studies that can be proposed. The Online Engagement and Teaching Hub is, moreover, characterized by diverse scholarly references: each teaching strategy is illustrated by considering sources in the scholarly literature and offering hyperlinks that direct directly to more expert sources, such as to the Teaching Learning Centers most knowledgeable in each teaching methodology. The project sources on declined provide an interesting overview, characterized by cross-cutting contributions that put the specific expertise of the stakeholders involved at the service of the academic community.

Specifically, the insights on which the Online Engagement and Teaching Hub focuses relate to the following areas of focus:

- Challenges: to each educational and training challenge proposed is associated a teaching strategy useful to cope with any difficulties that the teacher encounters within the classroom – concrete or digital. With each teaching strategy, the center associates the relevant implementation time, scientific theory of reference, related potential activities, and supportive technologies that can be used. This section represents a veritable blueprint that can be declined, to the different cases, according to the learning needs we target.

- Technologies: it starts with the affirmation that technology-mediated learning is an essential element in the practice of teaching and learning, and a series of digital tools useful for teaching practice are proposed, characterized by guidelines for purposes appropriate to educational contexts.
- Activities: useful activities are presented to address and support the challenges afferent to the challenges section: a series of guides and key considerations – from a practical perspective – aimed at promoting active and cooperative learning among students and with teachers.
- Theories: the updated theoretical approaches and scientific insights, based on the relevant scientific literature and academic research conducted by the university in question. Theories are considered useful tools to design effective online learning environments. A wide range of theories is, therefore, presented, such as, for example, social learning theory and cognitive load theory.
- Case Studies: the center allows the teacher to present a "case study" and obtain from the experts a proposal about the tools, strategies and technologies useful to achieve the learning objectives that the teacher has placed in focus in the proposed syllabus.

It is evident, then, how the Covid-19 pandemic has promoted a new way of experiencing and proposing not only teaching but also supporting it. These virtuous examples of Teaching and Learning Centers Online highlight precisely how quality in relation to digital teaching and learning comes from best practices. Academic quality in higher education, then, should allow itself to be led toward a guided and conscious transformation process that aims to ensure educational content that is studentcentered, accessible, and effective in terms of design and delivery [8].

4 Conclusions

It has been pointed out that the Covid-19 pandemic has put academic institutions before a profound change, overturning the certainties and patterns that, until then, had characterized the delivery of teaching in almost all universities in the world. Having shaken up educational and training practices, however, allowed for the emergence of a series of good new practices with an innovative character that, slowly, not only supported a moment of global educational crisis but, rather, made practice of innovative models that, until then, had remained unexplored [3]. Certainties have given way to creativity and innovation: the proposals analyzed and described by the Horizon report demonstrate this: supporting teaching, training and learning practice is a first step in promoting quality learning the development of academic institutions.

The role that Teaching and Learning Centers have played in such change puts at the center the need for a focus on them that needs to be nurtured and promoted, not only in the individual universities of reference, but from a cooperative and collaborative perspective [30]. It would be interesting, in fact, to create a networking of TLCs at the national and international level, aimed at sharing models, best practices, and teaching and research experiences that would allow for constant and sustainable development. An interesting lunge to be integrated within this training practice refers, moreover, to the role that technical administrative staff play within academic institutions: integrating, within these centers, training to administrative staff would, in fact, make it possible to aim for an improvement also in fundamental and supportive services to students and faculty. The heart of higher education is characterized, in fact, by each component of the academic community: students, administrative staff and faculty need to relate to each other and to them in order to ensure that everyone, no one excluded, has a learning and working environment that is stimulating, innovative and characterized by well-being.

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How Covid-19 Affected the Slovak and Czech Mathematics and Physics Teachers' Use of Resources

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Abstract. The paper describes a study realized with Slovak and Czech teachers of mathematics and physics. The pandemic and the sudden appearance of new types of resources, which appears in the preliminary results of the pilot study of the Horizon 2020 MaTeK project (in which are authors of this paper involved) implied the need to explore if teachers' behavior in resource use was changed due to Covid-19 pandemic in a long-term or only during the time of lockdown and shortly afterward. Therefore, a questionnaire study focused on different use of resources with two lines of interest: differences between countries and differences between mathematics and physics teachers. The result of this study provides some crucial information about how teachers dealt with lockdowns and what the critical points and gaps in resource use are. Some of these factors can be starting points for further research or can provide helpful information for authors of curricular resources.

Keywords: resources · mathematics · physics · education · covid-19 · lockdown · methods

1 Introduction

More than 94% of all students in the world were affected by schools getting closed when the global pandemic hit in 2020 [1]. With the sudden shift to distance learning new approaches to teaching, lesson planning and classroom preparation had to be adopted by teachers. The need to adjust the methods commonly used by teachers or to come up with completely new ones sometimes led to seeking and researching of different curricular resources. Sharing of those resources and cooperation among the teachers increased as well [2]. The education shifted to online environments, teachers discovered lots of previously not frequently used applications or websites and many completely new materials of different kinds were created by teachers who often shared them online (e.g. in teacher groups on Facebook, in online libraries, on websites for teachers, etc.) [1]. The amount of online educational videos (YouTube, Khan Academy, etc.) increased as many

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teachers were sharing their lessons online. Some teachers claim that their technology competence was boosted in that period [3] and that they feel more confident in using them now [4].

Statements of this kind caught our attention as they were quite relevant for the project[1] (more on which later) of which we are a part of. Members of the project were just in a preparation phase of a questionnaire whose goal was to assess teachers' use of resources in lesson preparation, during the classes and in connection to reasoning and proving. As the results could be influenced by the pandemic and the sudden appearance of new types of resources, the need arose to explore if teachers behavior in resource use was changed due to Covid-19 pandemic in a long-term or only during the time of lockdown and shortly afterwards. We were interested in ways in which mathematics and physics teachers' use of resources has changed. Of course, in accordance with [4], we expected increase in the use of technology and new software environments during the pandemic. However, we were also interested if teachers still use some of these resources post Covid-19 as several studies (such as [5]) suggest positive impact of online resources on learning and even recommend using these practices post Covid-19.

The distance form of learning did not only influence the resources used, but also the methods and strategies not typically used with the given curriculum [6]. These methods sometimes reflected the different classroom arrangement, distractions in the environment or the lack of motivation digital technologies might bring [7]. The methods that teachers found (more) useful during these times might also have influence on the way they teach now and the resources they started using.

2 Methodology

The purpose of our research was to inform the main study focusing on teachers´ use of resources (where data is collected using Questionnaire A [see Fig. 1]) and to assess the impact of Covid-19 on use of resources in classes after the lockdown. To collect the data for that purpose a Questionnaire B was developed. The pilot study for the main study (Pilot for Questionnaire A) served us as a basis for the Questionnaire B about the Covid-19 impact (see Fig. 1).

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[1] Horizon 2020 project MaTeK (Enhancement of Research Excellence in Mathematics Teacher Knowledge).

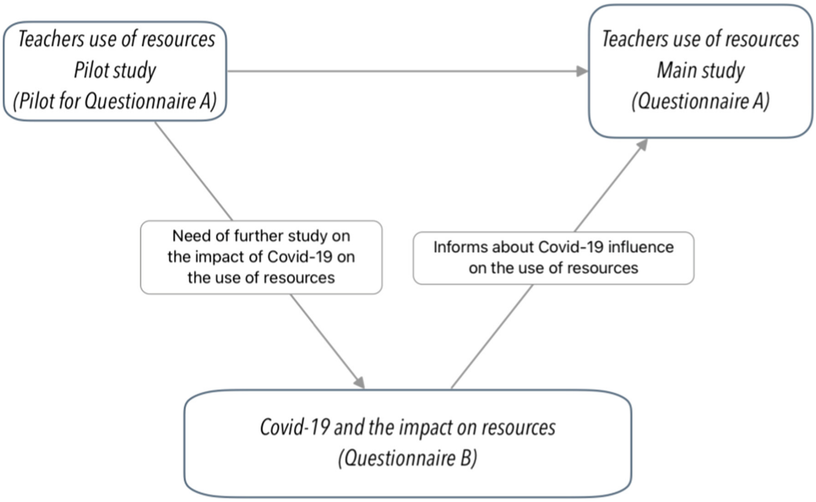

Fig. 1. Main study scheme and the place of this study in larger picture of MaTeK research.

2.1 Basis for the Questionnaire B

Our tool for data collection is grounded in a questionnaire (Questionnaire A) which was developed by the consortium of the MaTeK project. In this project, universities from five countries are cooperating: Comenius University in Bratislava (Slovakia), Charles University in Prague (Czech Republic), University of Palermo (Italy), Norwegian University of Science and Technology in Trondheim, (Norway) and Middle East Technical University in Ankara (Turkey). The goal of this research is to assess what curricular resources teachers use to plan their lessons, for assessment, to refresh the curriculum, to get inspiration and to plan lessons focusing on reasoning and proving. The questionnaire consists of 29 items, where six of them were connected to the use of resources. One of the questions included in Questionnaire A asked: "To what extent did situation around Covid-19 change the way in which you use resources now?" Teachers were to indicate their answer on a six-point Likert scale. The scale lowest value (1) corresponded with: "No change at all." while the highest (6) with: "To a great deal." If teacher answered that any change was present, the upcoming open-ended question appeared: **"**In what ways did the Covid-19 situation change how you used to use resources and how you use them now? Please describe."

A Pilot for Questionnaire A among primary (pupils age 6–15) and secondary (pupils age 15–19) school mathematics teachers from different countries participating in the Horizon 2020 project MaTeK was conducted. It was filled in by 108 participants. The results of the closed question related to Covid-19 can be seen in Fig. 2. Mean value selected on a Likert scale is 3.66, meaning some change in the use of resources was present in our sample, but not as huge as was. From open ended question we could also observe that the change was more or less individual and not country or school type dependant. The answers varied from: "I have all the materials I use in my computer, so Covid has not affected me at all." to:"I am still creating materials in Google Classroom,

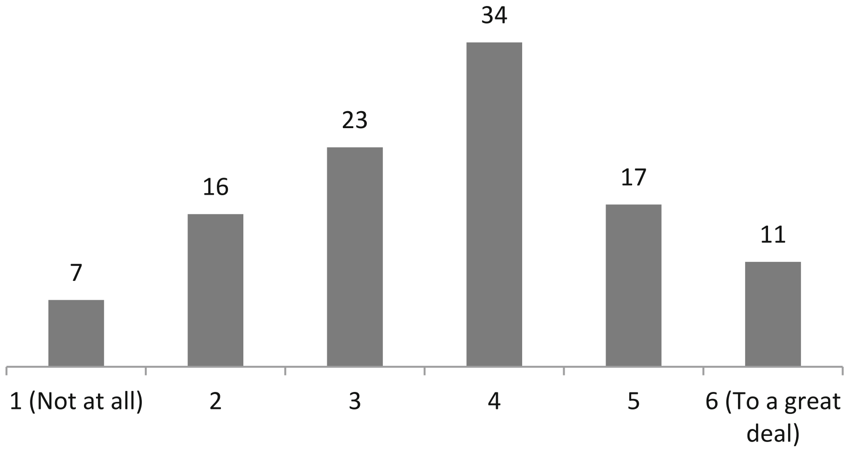

Fig. 2. How Covid-19 influenced the way in which you use resources now?

inserting documents for self-study or revision there and creating interactive worksheets." Inconclusiviness of these results showed the need for deeper study on the impact of Covid-19 and schools lockdown on teachers' use of resources and methods. The need to understand the use of resources and possible change in post-covid world arose. We also wanted to focus specificaly on mathematics and physics teachers.

2.2 Change in Use of Resources Due to Covid-19 (Questionnaire B)

Questionnaire B was developed based on questionnaire A which was internally and externally valid. Thus we consider the questionnaire B to be valid as well. The results mentioned above served as a starting point from which we developed a new, more thorough questionnaire about the impact of Covid-19 on the use of resources by mathematics or physics teachers. This new questionnaire was developed with specifics of Slovak and Czech school systems in mind. We decided to focus on these two countries as our school systems are close to each other as these countries share common history and the results might be compatible (see [8]). Purpose of this questionnaire was to find answers to the following research questions:

- RQ1: Which methods did teachers find useful and working for pupils during the lockdown?
- RQ2: What changed in teachers' use of resources during and after the lockdown?
- RQ3: Do teachers still use new methods or approaches from RQ1 now? If so when, why and what for?

The questionnaire comprised two parts: First, teachers indicated what subjects they teach (Mathematics, Physics, Chemistry, Biology, Geography and Other) and based on their answers questions about mathematics, physics, or both appeared. These questions were of all types – open, semi-open and closed. Teachers were asked about their use of resources before, during and after Covid-19 schools lockdown. They were to select which resources they used when and state what for and why. Resources were accompanied by several local examples. The same questions were asked about the methods (see Fig. 3). Second part consisted of demographic questions. Whenever teachers were to select from an array of options, there was an option *other*, where they could fill in their own ideas.

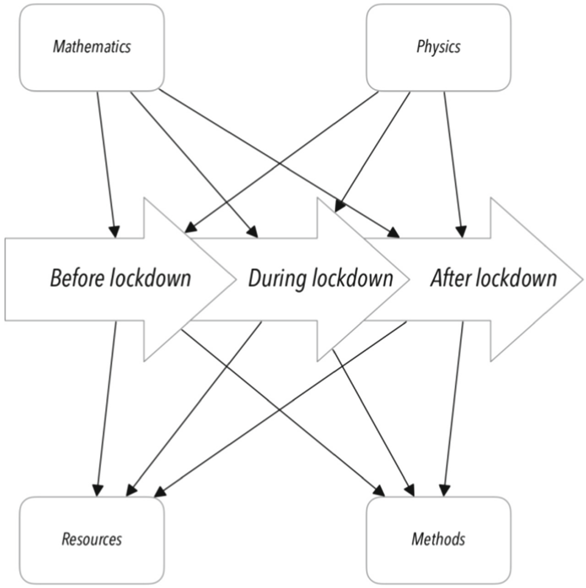

Fig. 3. Scheme of different stages in which the questions were posed.

The questionnaire included questions asking what resources the teachers used but for some reason are not using anymore, and what resources they tried to use and remain using.

Only the data from teachers who filled in the questionnaire entirely were used. Answers where contradicting answers could be found were excluded as well. This left us with 140 respondents (see Table 1 for more details, the sum of totals is greater than 140 as many teachers teach both subjects).

Table 1. Number of participants.

	Mathematics	Physics
Slovakia	62	50
Czech Republic	52	31
Total	114	81

The data was analysed using descriptive statistics. First, data for mathematics were analysed at each country separately, then for physics data were analysed in the same manner. These sets of data were then compared with each other. Conclusions were then drawn based on these as well as on several interviews (4 from Slovakia, 5 from Czech Republic) which helped us to understand more clearly some uncertainties that arose from questionnaire results.

3 Results and Conclusions

Since we were working with two groups of teachers in both countries, we analyzed obtained data by subject taught (mathematics, physics) and compared those results between countries and subjects.

3.1 Teachers of Mathematics

Most and Least Used Resources Before and During the Covid-19 Lockdown. As for the resources mathematics teachers used the most and the least before the pandemic, three extreme valued items (three most used, and three least used) from our sample are summarized in Table 2.

Table 2. Most and least used resources before Covid-19 by mathematics teachers.

Most used resources before Covid-19		Least used resources before Covid-19	
Resource	Number	Resource	Number
Textbooks	106	Social media	9
Own materials prepared in the past	91	Professional periodicals (journals) for teaching mathematics	16
Consultation with the mathematics teachers in my school	85	Online professional platforms/libraries for (teaching) mathematics	22

The table was compared with the most and least used resources during Covid-19. These results are summarized in Table 3.

Table 3. Most and least used resources during Covid-19 by mathematics teachers.

Most used resources during Covid-19		Least used resources during Covid-19	
Resource	Number	Resource	Number
Textbooks	85	Professional periodicals (journals) for teaching mathematics	10

(*continued*)

Table 3. (*continued*)

Most used resources during Covid-19		Least used resources during Covid-19	
Resource	Number	Resource	Number
Own materials prepared in the past	85	Social media	25
Online databases or websites for sharing resources created by teachers	77	Online professional platforms/libraries for (teaching) mathematics	37

The tables show that the first two most used resources remained unchanged during the Covid-19 lockdown. There is however rise in use of *Online databases or websites for sharing resources created by teachers.* As for the least used resources, they remained unchanged, only the order is different. If we take a look at other resources (see Fig. 4) we can observe the expected rise in use of several online resources such as *Online video platforms* or *Digital math apps/virtual manipulatives.*

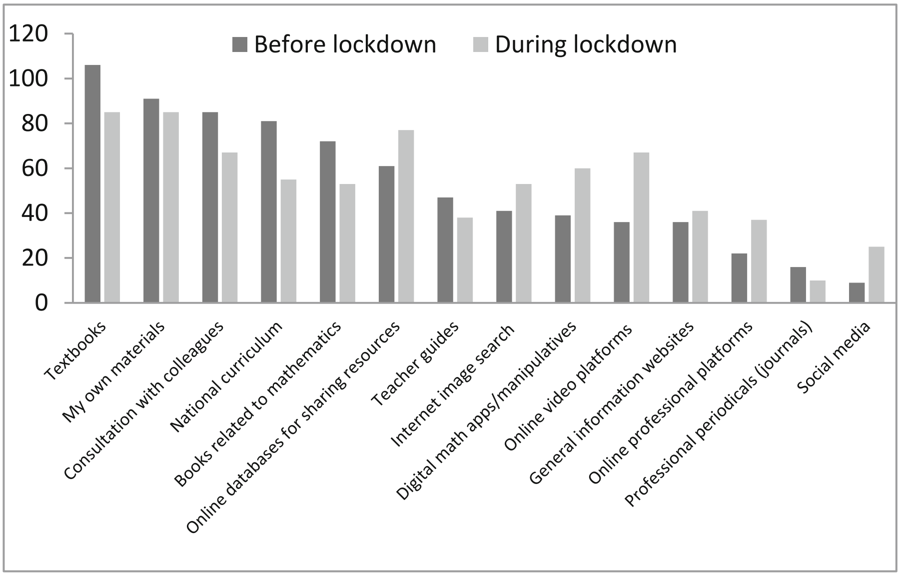

Fig. 4. Resource use by mathematics teachers before and during Covid-19 comparison.

Resources Tried but not Used Frequently During Covid-19 Lockdown. Despite the rise in those two categories in our sample, interesting results were found when analysing the answers for the resources teachers tried to use during the Covid-19 lockdown but did not keep on using regularly during the lockdown. The *Online video platforms* and *Digital math apps/virtual manipulatives* were tried but nearly every third teacher who tried these abandoned these resources later. The reason for this may be that there are already made videos on YouTube, and the teachers could not find exactly what they needed. Another reason may be, regarding GeoGebra, for example, that teachers who did not know GeoGebra before may have taken too long to prepare and the learning curve was too steep. Furthermore, regarding GeoGebra, a primary school teacher commented:

> "During distance learning GeoGebra turned out not to be the tool I needed. Pupils need to observe the way in which to use compass and ruler. Thus I eventually started using simple software for interactive boards in its place, where I could work with these instruments."

Thus it may be that some teachers preferred apps and programs in which pupils could see directly how to work with a ruler and a compass.

Resources Discovered During Covid-19 Lockdown. The questionnaire also explored which resources teachers had discovered during Covid-19 schools lockdown, and we created two groups based on whether they were still currently using these resources, i.e. in face-to-face teaching, or not for some reason. In the Table 4 we can see that several respondents claim to discover the *Textbooks* and are still using them. An explanation for this may be that several publishers have made mathematics textbooks available online, and therefore online textbooks may have come up when teachers were searching for resources and discovered new ones they previously did not use either in paper or digital form. Further, we can note that many teachers have discovered *Online databases or websites for sharing resources created by teachers* and are still using them today. One of the teachers stated during the interview:

> "During lessons focused on students' self-study, I use YouTube videos, or prepared study materials found on other teachers' websites, or books. Pupils study the topic and then work in groups to complete a worksheet. ... I am always looking for suitable worksheets for pupils on zborovna.sk (Online database for sharing resources created by teachers, popular among teachers in Slovakia). From the (school official) website I still assign homework to pupils."

Since we know that some sites contain poor quality materials prepared for teachers, here we see an opportunity for future mathematics teachers, i.e., mathematics education students under the guidance of experienced supervisors in our faculties to produce high quality materials for mathematics teachers.

Results related to the resources teachers discovered and either still use or do not use anymore after the Covid-19 lockdown are summarized in Table 4.

Table 4. Number of mathematics teachers who discovered a given resource during Covid-19 lockdown and still do/do not use it after Covid-19 lockdown.

Resource discovered during Covid-19 lockdown	Still use	Do not use anymore
Official/national curriculum	5	3
Textbooks	**11**	**1**
Teacher guides or textbook teacher editions	8	1
Books related to mathematics or teaching mathematics other than textbooks	8	1
Professional periodicals (journals) for teaching mathematics	1	7
Consultation with the mathematics teachers in my school	8	2
Own materials prepared in the past	15	3
Online databases or websites for sharing resources created by teachers	**31**	**7**
Online professional platforms/libraries for mathematics or teaching mathematics	21	24
Online video platforms (e.g. YouTube, Khan Academy)	37	24
Digital math apps/virtual manipulatives (e.g. WolframAlpha, PhET, GeoGebra)	19	18
Social media (e.g., Facebook or WhatsApp group of math teachers)	20	19
General information websites (e.g. Wikipedia, blogs)	13	14
Internet image search engines or image libraries	13	7

We also looked separately at the results of mathematics teachers from Slovakia and the Czech Republic. However, in terms of resource use, the differences were minimal and therefore we can consider the two countries comparable in this research. As an example we can state:

- In Slovakia, before the arrival of the Covid-19 pandemic, teachers used textbooks, the national curriculum and their own materials as the primary resources in the first three places. During distance learning, teachers most frequently used textbooks, their own materials and, in terms of online resources, online databases or teacher-created sites for shared materials.
- In the Czech Republic before the Covid-19 pandemic the top three places are the same resources as above for both countries – textbooks, own materials and consultation with colleagues. During distance education, the most frequently used resources were textbooks, own materials and, as far as online resources are concerned, digital mathematical applications.

Methods Mainly Used Before and During Covid-19 Lockdown. As for the methods, we first asked about the main methods and forms of working with pupils before the arrival of the Covid-19 pandemic, and then about the period of distance learning. The open-ended question asked respondents to comment on the present, i.e. on the methods and forms of work during the face-to-face teaching period. Looking at the Table 5, we can see that more teachers started using project-based learning during the distance learning period. We can also notice that there is only a small decrease in problem-based learning.

Table 5. Methods mainly used before and during the Covid-19 lockdown by mathematics teachers.

	Methods mainly used before Covid-19 lockdown	Methods mainly used during Covid-19 lockdown
Interpretation, explanation	103	102
Open discussion in the classroom	91	76
Working with a book or a text	68	60
Using motivation information or activity (e.g. historical interest…)	55	38
Using activating and re-activating methods (e.g. didactic games, brainstorming…)	51	44
Cooperative teaching	39	26
Teaching through problem solving	**40**	**36**
Project-based teaching/learning	**24**	**29**
Using heuristic methods	23	17

However, respondents from both countries are included in this table. If we look at the countries separately (see Table 6), we find that in Slovakia teachers have started to use project-based learning more in distance learning. When we look at the respondents from the Czech Republic, we see that during the period of distance education they included problem-based learning in the teaching process to a greater extent.

Table 6. Methods mainly used before and during Covid-19 lockdown in Slovak and Czech Republic by mathematics teachers.

	Methods mainly used before Covid-19 lockdown		Methods mainly used during Covid-19 lockdown	
	Slovakia	Czech Republic	Slovakia	Czech Republic
Interpretation, explanation	52	51	52	50
Open discussion in the classroom	53	38	46	30
Working with a book or a text	40	28	34	26
Using motivation information or activity (e.g. historical interest…)	31	24	24	14
Using activating and re-activating methods (e.g. didactic games, brainstorming…)	33	18	26	18
Cooperative teaching	25	14	15	11
Teaching through problem solving	**27**	**3**	**23**	**13**
Project-based teaching/learning	**15**	**9**	**22**	**7**
Using heuristic methods	13	10	11	6

These two methods are also indicated in the Table 6. The number of teachers who incorporated *project-based learning* into their teaching might have increased during the distance learning period due to some teacher's inexperience in the digital environment and therefore they tried to shift the responsibility to the digital space of younger pupils, who are, according to some, "born with technology in their hands". As far as *teaching through problem solving* learning is concerned, its rise could also be explained by inspiration in videos (use of which surged) that start with a problem, followed by an explanation. Since for most teachers in both countries, the frontal presentation is the most natural form of classroom work, the lockdown and the work in the online environment has opened their eyes in differently organized classroom.

In an open-ended question, respondents were asked to describe the methods and forms of work that they used in distance learning and that they currently use in face-to-face teaching. Teachers commenting on *teaching through problem solving* and *project-based learning* mentioned that they usually include activities of that kind either at the beginning or at the end of the thematic unit. Teachers also mentioned that they consider it an advantage that pupils can work together, explain things to each other and have more time to do the assignment. They also mentioned the fact pupils can use a variety of resources, including online ones even in classrooms.

3.2 Teachers of Physics

Most and Least Used Resources Before and During the Covid-19 Lockdown. The Tables 7 and 8 show the most and least used resources selected by physics teachers in our sample.

Table 7. Most and least used resources before Covid-19 by physics teachers.

Most used resources before Covid-19		Least used resources before Covid-19	
Resource	Number	Resource	Number
Textbooks	72	Social media	6
Official/national curriculum	54	Online professional platforms/libraries for (teaching) physics	13
Own materials prepared in the past	53	Professional periodicals (journals) for teaching physics	20

Table 8. Most and least used resources during Covid-19 by physics teachers.

Most used resources during Covid-19		Least used resources during Covid-19	
Resource	Number	Resource	Number
Online video platforms	56	Professional periodicals (journals) for teaching physics	10
Own materials prepared in the past	54	Social media	16
Textbooks	52	Online professional platforms/libraries for (teaching) physics	22

In terms of the resources that teachers tried and used regularly during distance learning, there was no change present in the last three places (except for the order), but there was in the first two. It can be noticed (see Fig. 5) that online video platforms have moved from 7th place to first. As for the other online resources, they have also moved up in the ranking. We expected such results, so our assumptions have been confirmed.

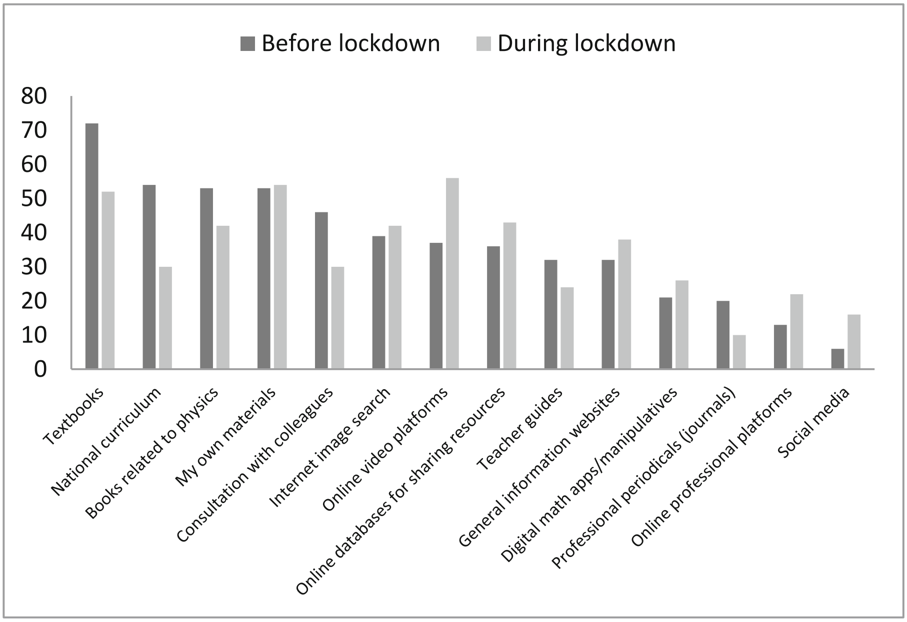

Fig. 5. Resource use by physics teachers before and during Covid-19 comparison.

Resources Tried but Not Used Frequently During Covid-19 Lockdown. We can note the interesting fact that when it comes to books related to physics or teaching physics other than textbooks, more teachers included them in distance education than not (see Table 9). The possible reason for using this resource could be in teachers' ability to assign homework for the students to study the information on a certain topic or unit by themselves. One teacher mentioned such a use:

> "Different books – lots of interesting things – I give out the articles to the pupils and then they have to mark in the text what they knew already, what is new for them... or they can make a short excerpt from the text or create a comic book or crossword puzzle based on it."

If we look at online resources, we can notice that physics teachers were too more likely to use them regularly during distance learning than not. However, we expected this fact, as almost everything was online at that time.

Table 9. Resources tried and either used frequently or not anymore during the Covid-19 lockdown.

	Tried and frequently used during Covid-19 lockdown	Tried but did not keep on using during Covid-19 lockdown
Official/national curriculum	30	18
Textbooks	52	13
Teacher guides or textbook teacher editions	24	7
Books related to physics or teaching physics other than textbooks	**42**	**13**
Professional periodicals (journals) for teaching physics	10	16
Consultation with the physics teachers in my school	30	12
Own materials prepared in the past	54	5
Online databases or websites for sharing resources created by teachers	**43**	**12**
Online professional platforms/libraries for physics or teaching physics	**22**	**14**
Online video platforms (e.g. YouTube, Khan Academy)	**56**	**11**
Digital physics apps/virtual manipulatives (e.g. WolframAlpha, PhET, GeoGebra)	**26**	**15**
Social media (e.g., Facebook or WhatsApp group of physics teachers)	16	14
General information websites (e.g. Wikipedia, blogs)	**38**	**12**
Internet image search engines or image libraries	**42**	**6**

As in the case of mathematics teachers, we wanted to know which resources teachers tried and kept on using but also which they decided not to use frequently during Covid-19 lockdown. The results for physics teachers are shown in Table 10.

Resources Discovered During Covid-19 Lockdown. In the last question, which was related to resources, we asked physics teachers which resources they had discovered during distance learning, and of those resources which they were still using during face-to-face teaching, or, on the contrary, for some reason they were no longer using them at present. Results are shown in the Table 10. We can note that 14 respondents indicated that they discovered the possibility of consulting with colleagues thanks to distance learning, and most of them still use this possibility. From interviews we learned that teachers started consulting more technical things with their colleagues and wanted to know how to teach something better during the Covid-19 lockdown.

Table 10. Number of physics teachers who discovered a given resource during Covid-19 lockdown and still do/do not use it after Covid-19 lockdown.

Resource discovered during Covid-19 lockdown	Still use	Do not use anymore
Official/national curriculum	5	6
Textbooks	9	5
Teacher guides or textbook teacher editions	3	0
Books related to physics or teaching physics other than textbooks	13	4
Professional periodicals (journals) for teaching physics	4	8
Consultation with the physics teachers in my school	**10**	**4**
Own materials prepared in the past	12	5
Online databases or websites for sharing resources created by teachers	13	9
Online professional platforms/libraries for physics or teaching physics	18	13
Online video platforms (e.g. YouTube, Khan Academy)	**33**	**5**
Digital physics apps/virtual manipulatives (e.g. WolframAlpha, PhET, GeoGebra)	19	10
Social media (e.g., Facebook or WhatsApp group of physics teachers)	9	12
General information websites (e.g. Wikipedia, blogs)	16	9
Internet image search engines or image libraries	16	2

Of the online resources, video platforms are predominant among our respondents in the sense that they have discovered them, started using them, and still use them to some extent in the classroom. Given the nature of the responses, it can be concluded that a large proportion of these are videos of experiments (not only those that would be inappropriate for home or school experimentation for safety reasons, but also those for which, for example, the school does not have the equipment). Looking more closely at the data from Slovakia, teachers tend to embed these video experiments in worksheets for pupils to work on at school or at home. As can be seen from the answer below, there are several reasons for including videos in the classroom:

> "Before the pandemic, we did experiments with pupils in the classroom, and thanks to them we often created a problem situation. Sometimes it happened that for various reasons it was not possible to carry out the experiment in school conditions, so I resorted to video or animation of the phenomenon under study. During the pandemic-related online classes, we used video demonstrations and various applets much more often in the classroom, so that I could create a problem situation or attract the attention of the pupils. Also, pupils carried out various physics measurements via applets, in case the home conditions were not sufficient to carry out the real experiment and the measurement associated with it. After returning to the school, I opted for the use of a short video in the lessons to demonstrate and arouse the interest of the pupils with greater frequency. Also, some of the measurements that the pupils did during the online lessons I later chose to do again in this form during the school lessons, as it was more illustrative, and every pupil could do the measurement."

Methods Mainly Used Before and During Covid-19 Lockdown. Table 11 shows teachers' methods, primarily before and during the Covid-19 lockdown. We noticed that all the numbers decreased during the Covid-19 lockdown, and the order changed. Project-based teaching/learning was used more than other methods during the lockdown period. Teachers confirmed and explicitly told us that they more frequently used projects as assignments for their pupils. They saw many advantages because pupils could cooperate in an online environment, look for the information needed on the internet, and have more time to do so than in a school environment. Interviews with physics teachers also suggest that teachers who frequently used experiments in their classes before the lockdown also tried to include experiments during the lockdown. For that purpose, mainly online videos, online applications, or project-based teaching were used.

Table 11. Methods mainly used before and during the Covid-19 lockdown by physics teachers.

	Methods mainly used before Covid-19 lockdown	Methods mainly used during Covid-19 lockdown
Interpretation, explanation	70	56
Open discussion in the classroom	59	49
Working with a book or a text	42	37

(*continued*)

Table 11. (*continued*)

	Methods mainly used before Covid-19 lockdown	Methods mainly used during Covid-19 lockdown
Using motivation information or activity (e.g. historical interest…)	47	39
Using activating and re-activating methods (e.g. didactic games, brainstorming…)	37	24
Cooperative teaching	23	14
Teaching through problem solving	40	27
Project-based teaching/learning	**33**	**30**
Using heuristic methods	19	13

3.3 Discussion

The most used resources before lockdown in both countries and subjects were *textbooks* and *own materials prepared in the past*. On the other hand, teachers did not usually use *online resources* or *journals for teaching mathematics or physics.* During the lockdown all the teachers frequently used *digital applications (such as GeoGebra, WolframAlpha, etc.).* In comparison to pre-lockdown situation the greatest surge was present in *online video platforms (such as YouTube, Khan Academy).* There was also increase in the use of *online databases or websites for sharing resources created by teachers.* Other uses of resources remained similar to pre-lockdown situation. Several teachers responded that they only tried these online resources but did not use them frequently during the lockdown. We were also interested in resources that teachers discovered during the lockdown and do still use them nowadays. Results suggest that teachers still use *online video platforms* and *websites where teachers can share their materials with others.* They also still use online versions of *textbooks*, as well as *consultations* with other teachers from their school.

4 Conclusion

The results of the research will be used within the MaTeK project as part of an intervention in the undergraduate course Didactics of Mathematics and Physics. Expected rise in use of technology related resources was visible in our sample. In concordance with [9] several teachers shared that they feel more confident to use different apps and digital technologies in their classrooms than before the schools lockdown. As online teaching might remain part of everyday life, we consider it important that student teachers, i.e. future mathematics or physics teachers, are familiar with the different resources and methods that the interviewed teachers mentioned in the questionnaires. It is also important for student teachers to be familiar with the materials found online and also be able to critically evaluate them. Results show these "new" resources teachers started to work with during the lockdown period did not replace the resources previously used, but enriched teachers existing "toolbox". As Pepin [10] says: "Introducing a new resource does not necessarily lead to the replace end of the old one but leads to a re-organization of a teacher's resource system." This reorganization was apparent in interviews with the teachers, who claimed to use different resources they used in different ways or in combination with newly discovered ones.

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The "Courage Companion" – An AI-Supported Environment for Training Teenagers in Handling Social Media Critically and Responsibly

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Abstract. The provision of toxic content and misinformation is a frequent phenomenon in current social media with specific impact and risks for younger users. We report on efforts taken in the project Courage to mitigate and overcome these threats through dedicated educational technology inspired by psychological and pedagogical approaches. The aim is to empower adolescents to confidently interact with and utilize social media and to increase their awareness and resilience. For this purpose, we have adopted approaches from the field of Intelligent Tutoring Systems, namely the provision of a virtual learning companion (VLC). The technical system is a browser-based environment that allows for combining a controllable social media space with a VLC as a plugin. This environment is backed by an API that bundles Machine Learning and Natural Language Processing algorithms for detecting and classifying different types of risks. The pedagogical scenarios that are supported by this technical environment and approach range from chat-based dialogues to more complex narrative scripts.

Keywords: AI-based learning support systems · Intelligent tutoring system (ITS) · Learning Companion Systems · Recommendation · Awareness tool · Misinformation

1 Introduction

Misinformation, toxic content, and online harassment have become serious problems in social media channels. This affects the younger generation in a specific way. Taking up this challenge, the Courage project[1] aims at empowering adolescents to confidently

[1] Courage Project (EU), Social Media Companion Safeguarding and Education Students, www.couragecompanion.eu, Oct 2022.

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https://doi.org/10.1007/978-3-031-29800-4_30

interact and utilize social media. We take a multi-disciplinary approach building on psychology and pedagogy combined with data science and AI-driven approaches. Building on the tradition of Intelligent Tutoring Systems, we have developed a technical framework based on a Virtual Learning Companion enabling learning and interaction support with the aim to raise awareness and resilience on the part of the learners. The companion can be used in classrooms and informal settings providing a playful, adaptive and engaging setting in which adolescents interact with a social media environment under restrictions of pedagogical responsibility and guidance. One of these pedagogically motivated scenarios are narrative scripts that implement a collaborative learning flow pattern combined with counter-narratives to raise learners' awareness through the externalization and sharing, empathy, and perspective-taking.

The companion implements playful adaptive educational strategies to engage and scaffold adolescents interacting with a social media environment under restrictions of pedagogical responsibility. An example is via narrative scripts [1], such as the "Pyramid app," which implements a collaborative learning flow pattern combined with counter-narratives to raise learners' awareness through externalization and sharing, empathy, and perspective-taking. This paper illustrates how these goals are materialized in a web-based learning environment comprising a controlled social media platform and the VLC [2]. It is supported by an AI backbone using transformer-based models for robust classification of media content according to risks and considering related educational needs. The basic version of the VLC environment provides an Instagram-like social media platform as a closed world with controlled content. We have chosen PixelFed as an open-source framework to simulate the social media environment. While PixelFed holds the content, the virtual learning companion (VLC) is implemented as a plugin for the Chrome browser.

2 Related Work

2.1 ITS and Companion

As a particular version of intelligent tutoring systems (ITS), learning companion systems (LCS) personalize support and adaptive feedback through an explicit and possibly human-like agent that interacts with the learner [3]. The agent or learning companion guides the learner step by step and usually assumes a non-authoritarian role. The interface may include multimedia, interactive buttons, menus, text, speech, animation, diagrams, virtual reality, or other interactive techniques.

LCS interfaces typically incorporate natural language processing (NLP) to facilitate communication between LCS and the student. Tracking the learner's interactions with an LCS is part of learner modeling. For example, the LCS may ask the learner to explain the reasons behind answers as a reflective question for each step during the task. Learners could generate many explanations and articulate the reasons for their solutions that refine their understanding (self-regulated learning strategies) [4].

From the initial test of the VLC with learners in a simulated environment, the learners found VLC useful in determining reactions to the fact/fake news detection according to the learner's feedback and judgments on the environment's artifacts [5].

According to the definition of an adaptive system, one of the essential points for an adaptive tutoring system incorporating LCS is to respond flexibly to the learner's actions depending on the context and progression. This response can be implemented in the conversation as feedback to the user's text input, or it can respond to the user interaction in various ways, e.g., by suggesting a multimedia tutorial as a recommendation [6]. Modeling students as the basis for adaptive feedback in LCS tutorial dialogs can significantly increase learning gains for students with low and high prior knowledge [7]. The LCS can play many roles in an instructional context. For example, the role of a leader who suggests new ideas for learners to consider or the role of a critic who challenges learners' suggestions [8].

In answering the question, "How competent should the companion agent be to meet the learner's expectations and motivate the learner to continue working with the agent?" Hietala and Niemirepo [9] found that learners lose motivation when constantly using a strong and competent companion. Especially in the beginning, a companion who makes mistakes like a human is more effective. Nevertheless, introverted, and extroverted learners prefer knowledgeable and robust learning companions when faced with a challenging task or when dealing with a new topic.

Our virtual learning companion (VLC) supports features such as role-playing for users, providing adaptive feedback based on previous user interactions, scoring responses, and asking knowledge activation questions. In addition, analytics, and recommendations, which include taking input and displaying the information, are core functions of the VLC system.

2.2 Fake News and Challenges

Victoria L. Rubin defines a conceptual model for Fake News in the form of a triangle with the cornerstones Susceptible Host, Virulent Pathogen, and Promoting Environment. According to the model, Fake News spreads if and only if the three causal factors coincide. Three interventions propose to disrupt the interaction of the factors above: Automation to defuse the virulent pathogen, education to defuse the susceptible host, and regulation to make the enabling environment safe [10].

Automated AI-based approaches can detect toxic features and add labels to the information. An example of this approach is the LiT.RL News Verification Browser is a search tool for news readers, reporters, editors, or information professionals. The tool examines the language used in digital news websites to determine whether clickbait, satirical news, or Fake News. The classification provided by LiT.RL is not perfect and is not always suitable for public use. Multimedia formats are not supported [11].

Automated message validation systems based on NLP techniques may be helpful to assist content authors quickly checking standard features of misinformation. In addition, such systems could help teachers teach critical content evaluation skills or help information professionals reduce information overload for news consumers by filtering and flagging suspicious news [12].

The labeling strategy currently used on social media responds to any keywords that could potentially be Fake News (e.g., COVID -19 or vaccine)[2]. On the other hand, tracking and detecting fake content is tedious. For example, the deep manipulation of fake images makes it difficult for machines and humans to see fake content [13].

Another strategy to mitigate the vulnerable host and help learners develop their mechanisms to detect and counter such influences is education [10]. This approach can be divided into two main strategies: Raising awareness and improving learner bias. There are adventurous techniques to “improve bias and awareness”. For example, games and practices show learners how to use libraries and search engines to find truth and credible information from different contexts. To improve learner bias, we can also provide games that show how Fake News content creators create content on social media and what types of content are typically classified as misinformation.

To improve learners’ critical thinking rather than working on their biases, we can provide learners with a “Fact Checking Awareness Tool.” Such tools are designed to motivate learners to fact-check. According to the American Library Association (ALA), access to correct information from different contexts, without censorship and filtering, is the best way to counter misinformation and media manipulation [32].

The last point in the triangle is “regulation”. The legislative process should be methodically proactive and robust to prevent pathogenic “fakes” from reaching and infecting susceptible hosts in a conducive digital environment. The EU Commission has warned that social media companies face the threat of new regulations if they do not take prompt action against fake news[3]. Several programs have been launched under the leadership of the EU and international organizations to tackle disinformation related to the June 2020 pandemic[4]. The inventor of the WWW, Tim Berners-Lee, made the following comments at a recent Web Foundation conference: “Administrations must adopt rules and regulations for the digital age. They must ensure that markets remain competitive, innovative, and open. Moreover, they are responsible for protecting people’s rights and freedoms on the Internet”[5].

2.3 Integrating Machine Learning and Gamification into Learning Environments

To improve the efficacy of digital media literacy activity, gamification strategies could be a viable approach as technological advancements allow for more digitized learning environments. An evaluation of the integration of virtual reality tools shows promising results in terms of engagement of participants and learning outcomes [14]. Given the restrictions imposed by COVID-19, the development of gamified teaching tools can be seen to provide knowledge and enhance students’ collaboration during social distancing time.

A review by [15] finds that in particular STEM disciplines adopt this approach, but much should be done to improve the efficacy of those activities and maximize the

[2] Facebook and Instagram starting to identify and label ‘fake news, https://bit.ly/3VMxGSK, accessed Oct 2022.

[3] EU regulations over misinformation, https://bit.ly/3BqBBLw, accessed Jan 2022.

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participation rate by students. The challenges that gamification strategies need to address involves the relationship between user characteristic and engagement level but also how different knowledge's level impacts the design of the games.

In terms of platforms' design, [16] highlight the potential benefits that virtual learning companion (VLC) can get from adoption of AI– powered personalization of learning path, given a proper ethical oversight mechanisms related to ensure good recommendation of learning content and moreover VLCs should improve learners' personal autonomy, and benefits brought by the VLCs should outweigh risks.

3 Architecture

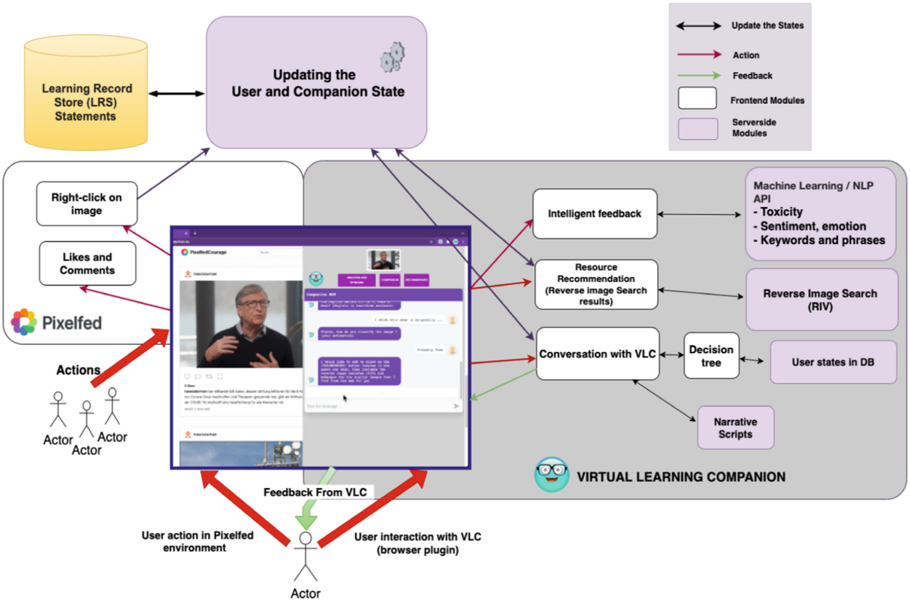

Fig. 1. Conceptual architecture of the Virtual Learning Companion system

The above architecture shows a web-based learning environment with a controlled social media platform and the VLC It is supported by an AI backbone that, for example, uses transformer-based models to robustly classify media content according to the risk and consider related pedagogical requirements. The basic version of the VLC environment provides an Instagram-like social media platform as a closed world with controlled scope. We chose PixelFed as the open-source framework to simulate the social media environment. While PixelFed contains the content, the VLC is implemented as a plugin for the Chrome browser. As shown in the architecture, learners can interact with both environments and receive prompt feedback from VLC during the scripted chat dialog guided by the Narrative scripts. Learners are instructed through (individual and collaborative) tasks that require judgments and comments on the information presented, typical of the image-based social media format (images with short text captions). The tasks are guided by a chatbot with narratives and adaptive counternarratives that challenges students' believes. A unique feature of the VLC is based on using "reverse imaging search" (RIS) engines that retrieve the same or similar images from different sources [5]. Learners are asked to judge whether a posted image and its caption are credible or fake by comparing the corresponding content and keywords retrieved by RIS from different sources.

The machine learning backend is integrated with the VLC framework as a separate, standalone API and provides support for threat detection through algorithms that can automatically analyze (social) media content. Several AI models have been developed as part of the project, and we will give a more detailed overview in Sect. 5 In general, the classifiers and content analyzers are focused on textual content and images, as these are the main contents of social media. Prediction results can be used to raise awareness of threats and support learners' education during their VLC interaction.

4 Implementations

In this project, to cover the different analyses from the COURAGE group, the modular model was suggested for the frontend and backend sections. On the server side, microservice architecture enables us to connect different APIs and services according to the empirical scenarios for the school's experiments. The frontend part has two main core features that allow the VLC to be used as an add-on for the browser (Chrome Browser plugging) and an easy-to-use chatbot that gets the conversation in the JSON format.

For example, in fake or fact scenarios in which the companion suggests related images from the web, the google API was operated to find similar images. This feature was disabled in the VLC for racism scenarios which aware the students of racism and discrimination in social media. The Modular architecture impower the system to be flexible and new component as (NLP API) add to the system [5].

5 VLC Technical Architecture

As mentioned in the Chrome extension were utilized as a browser plugin was implemented, and the ReactJS library was used to develop the chatbot inside the plugin, which can increase modularity (Fig. 2).

In the backend (server side), NodeJS and MongoDB store user interactions and states. Learning Locker is used for logging and visualization. We also implemented the Wit.ai machine learning tool to estimate user intentions. We have a data analysis dashboard to visualize the recorded logs and interactions in different forms (including bar charts and pie charts).

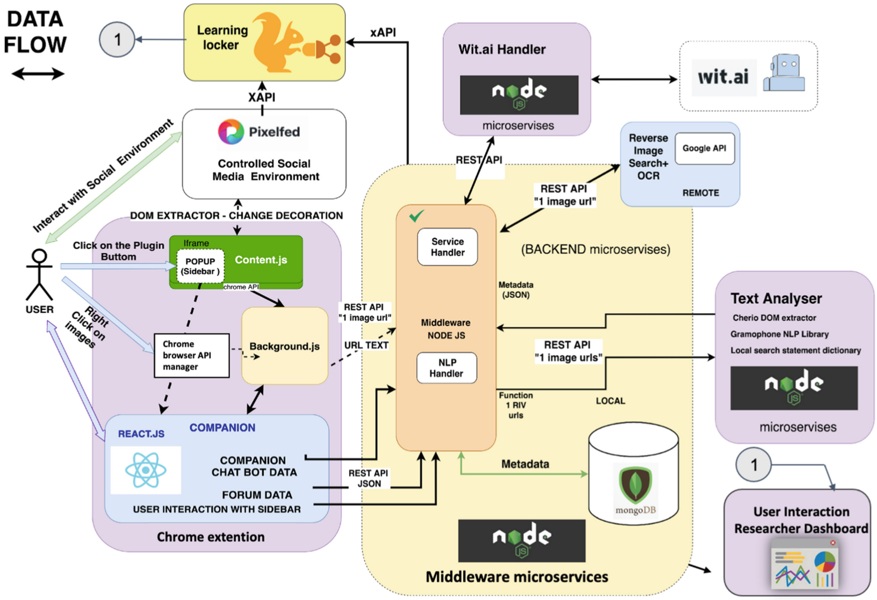

Fig. 2. Technical architecture of the courage companion for scenario that includes RIS module

5.1 Natural Language Processing and Machine Learning API

As mentioned in Sect. 3, the NLP and machine learning part of the project is integrated as a separate, standalone API in the overall VLC framework. To give a brief overview and clarify how this intelligent backend can contribute to social media threat education, we are describing the individual components and the deployment process of the API below.

In general, the structure can be divided into three main components, starting at the most basic level with **(1)** ***the trained models and code to run inference***, going over to **(2)** ***a framework to define model endpoints by wrapping up everything into an API*** and finalizing it by providing **(3)** ***support for deployment on any server***.

All implementations of (1) are based on python and we make use of well-established natural language processing frameworks, e.g., Hugging Face and machine learning frameworks, e.g. PyTorch and TensorFlow to build and train models and use them for making predictions. As also mentioned previously, these models are focusing on the analysis of textual content and images. Many of the integrated models are self-developed while we are also adopting some from literature, depending on their quality and required special use-case. The text analyzers can identify:

- Sentiment (English [17], Italian [18], Spanish [17], German [19])
- Emotions (English [20], Italian [18], Spanish [21])
- Hate speech (English, Italian, German [22])
- Fake news (English [23], German [24])
- Irony (English [25])

– Sexism (English [26])

In terms of image algorithms, we provide a self-developed model that can predict the body mass index (BMI) of persons based on a picture of their face which for example is helpful to identify threats arising of beauty stereotypes. In addition, we adopt models for gender identification [27] and object detection [28] as they support the identification of meta information in the overall image setting.

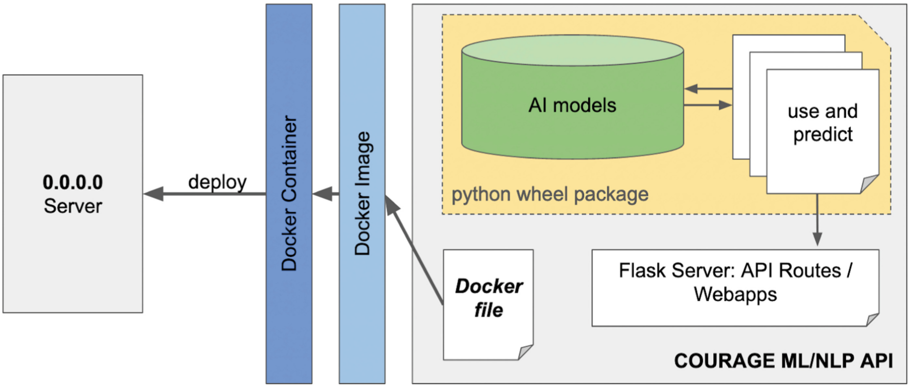

Fig. 3. Conceptual architecture and deployment process of the ML/NLP API

Figure 3 shows the conceptual architecture and the structuring of the deployment process of the NLP/ML API. The yellow box represents the algorithmic side as just described in (1).

Continuing with (2), the endpoint definition and API wrapper implementations are again based on python, and we are using the Flask framework to add routes or webapps to the backend. These establish the link to the algorithmic side and make AI models ready for access via http requests.

Finally, in step (3) the deployment is managed using Docker which requires a Dockerfile and allows to predefine python package and version requirements which makes it easy to deploy the API on any server without the need for prior installations.

Overall, our NLP/ML API is an easy-to-deploy, standalone application that can be used to analyze textual and image content containing state-of-the-art AI algorithms and we for example utilize it to identify potential threats on social media as part of the VLC framework as depicted in Fig. 1.

6 Educational Scenarios

Another Scenario that introduces the NLP/ML API is focusing on making a regular feed on social media more transparent to support users in identifying potential threats. For that, we are developing a web-interface mimicking Twitter and augment posts inside the timeline with additional information, e.g., automatic AI analysis results produced by the NLP/ML API. An example of this tool can be seen in Fig. 4.

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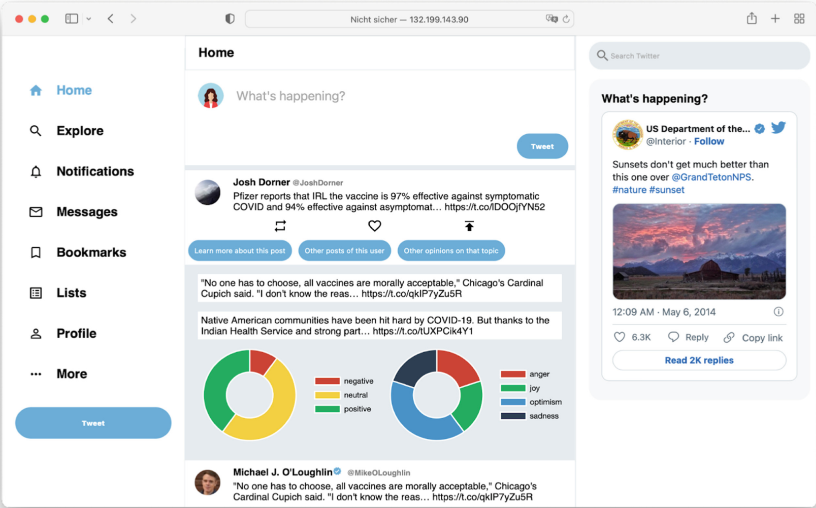

Fig. 4. Screenshot of an augmented feed in the Twitter scenario

The goal of this scenario is to clarify how automatic decorations are perceived by the users and if they support them in identifying threats. To measure these things, an in-between group study presenting this demo interface to one of the groups will be designed and the user performance on predefined tasks can be compared to their behavior using a regular feed without these decorations.

To enable the analysis of learner activities, all user actions are captured in a learning record store (Learning Locker) based on the xAPI description format. This includes interactions with the VLC as well as certain actions in the PixelFed space (e.g., selecting images). This architecture allows for aggregating action logs from different sources. A dashboard allows for analyzing and visualizing the logged actions.

The current version of the VLC environment provides learner guidance through scripted interaction and contextual information prepared for the closed environment.

To create an “open” version of the VLC, which will enable interacting with real social media environments, we are currently adding intelligent components for detecting toxic content and for analyzing learner comments. To be of actual practical use it is paramount that any such classifiers perform well enough. To achieve this, we incorporate state-of-the-art approaches that we have developed as part of the project and which have been demonstrated to be robust and competitive across classification tasks (e.g., toxic comment and fake news detection) and languages (Italian, German, English), e.g., [4]. We are also actively pursuing the possibility to use GCN based detectors which should allow us to flexibly integrate contextual information from different sources [29].

7 Conclusion

We report on the efforts made by Project Courage to mitigate and overcome this toxic social media content through a special education technology inspired by psychological and pedagogical approaches. The goal is to implement a series of tools based on the scenarios leading to empower young people to interact with and use social media confidently and to increase their awareness and resilience such tools were implemented in the similar works utilizing chatbot in the learning procedure in the social media like the i-LearnC# and FLOKI approaches [30, 31].

This approach presented a modular technical architecture for the web-based companion system. Modularity empowers us to be flexible and add new features and technical components based on the design with a minimal logical process. The Plugin can be employed in a controlled environment like PixelFed instance and open social media like Instagram and Facebook. The main components of the VLC are NLP/ML API, RIS module, and Narrative scripts. These modules can be enabled according to the learning scenario and will deliver to the user via interaction with the companion chatbot.

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In-Person/Online Attendance at an Educational Technology Workshop. A Study on Student Teachers' Perceptions at UniBg

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Abstract. This work presents the first phase of a descriptive study, realized at the University of Bergamo, which involved 102 student teachers participating in the "Educational Technology Workshop" of the degree course in Primary Education Sciences. The research objectives were: a. to describe student teachers' perception of the training experience gained in person or online during the workshop; b. to verify whether the way in which the students attended—face to face/online—influenced their perception of teaching with respect to strengthening their digital skills. The data were collected through an "ad hoc" questionnaire on student teachers' perceptions and were analyzed in a descriptive and correlational way. The survey revealed that the student teachers' perceptions regarding the teaching methods of the workshop changed according to the way in which they participated—those attending face to face understood the alternation between lessons and exercises better than those attending online, who, conversely, grasped the transmissive aspect of the workshop meetings better. It also revealed that the method of participation did not seem to have influenced prospective teachers' perception of their own digital skills. In general, university students' positive perception of training activities adapted online after the COVID pandemic was confirmed, and it was discovered that future teachers attending online are slightly more sensitive to the teaching methods through which the workshop is carried out and the integration of the workshop with the other training activities of the entire degree course.

Keywords: Teacher training · Digital skills · Presence/online workshop

1 Introduction

Comparative research on initial teacher training [1–5] has confirmed a growing trend toward "alternative" routes into the profession [6] with respect to which candidates are selected, complete the training, enter teaching and spend their first years in a real school context. Experience-based training activities are playing an increasingly central

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role in such pathway models: they are considered functional in guiding the judgment of prospective teachers and building the knowledge and skills needed to teach the disciplines. The "alternative" models for initial teacher education are very challenging for universities, which have to develop more flexible learning paths and interact with different roles and contexts, such as those of the school [7, 8]. Since teachers require technological knowledge and digital skills to teach on a daily basis, teacher training institutions and universities have to provide student teachers with the required experience in this field as well and offer not only theoretical but above all practical ways to develop their knowledge, skills and technological aptitude [9].

Like any other professional higher education course, in Italy, the "Primary Education Sciences" master's degree qualifies future teachers of kindergarten and primary school through a close integration between the university and the school environment and experimental organizational solutions that integrate courses, practicum and workshops [10]. From the perspective of strengthening teachers' digital skills (see European Parliament and Council of 18 December 2006), such a master's degree is required to train teachers to be capable of "using multimedia languages […] for the representation and communication of knowledge, for the use of digital content and, more generally, of simulation environments and virtual workshops also ensuring their accessibility by pupils with special educational needs" (MIUR, decree law no. 249/2010, 2010, p. 2). For this purpose, the DigCompEdu Framework offers 22 specific indicators for digital skills, organized into six areas [11, 12]: 1) Professional Engagement; 2) Digital Resources; 3) Teaching and Learning; 4) Assessment; 5) Empowering Learners; and 6) Facilitating Learners' Digital Competence.[1] In the DigCompEdu document, areas 2 to 5 express pedagogical and didactic ideas for the integration of technologies into education [11]; area 1 describes the use of technologies to communicate and collaborate with the whole school community; area 2 focuses on the effective and correct use of digital educational resources (including regulatory aspects); area 3 concerns the use of digital technologies in teaching practice; area 4 focuses on the use of digital technologies for assessing students' performance and learning needs; area 5 encourages the use of digital tools for personalization and the proposal of active learning activities; and area 6 promotes the digital competence of students through that of their teachers (Table 1).

Table 1. DigCompEdu Framework: areas and 22 indicators (adapted from [11])

Educators' professional competences	1. Professional engagement 1.1 Organisational communication 1.2 Professional collaboration 1.3 Reflective practice 1.4 Digital CPD

(*continued*)

[1] https://joint-research-centre.ec.europa.eu/digcompedu/digcompedu-framework_en.

Table 1. (*continued*)

Educators' pedagogic competences	2. Digital resources 2.1 Selecting 2.2 Creating & modifying 2.3 Managing, protecting, sharing 3. Teaching and learning 3.1 Teaching 3.2 Guidance 3.3 Collaborative learning 3.4 Self-regulated learning 4. Assessment 4.1 Assessment strategies 4.2 Analysing evidence 4.3 Feedback & planning 5. Empowering learners 5.1 Accessibility & inclusion 5.2 Differentiation & personalization 5.3 Actively engaging learners
Learners' competences	6. Facilitating learners' digital competence 6.1 Information & media literacy 6.2 Communication 6.3 Content creation 6.4 Responsible use 6.5 Problem solving

The DigCompEdu is an articulation of the DigComp [13], the framework that defines more generally the digital competences for European citizens among the eight key competences for lifelong learning. The DigComp document (version 2.2) was updated in March 2022 and provides for 21 competences grouped into five areas: 1) Information and Data Literacy; 2) Communication and Collaboration; 3) Digital Content Creation; 4) Safety; and 5) Problem Solving (Table 2).

Table 2. DigComp 2.2 conceptual reference model: areas and indicators (adapted from [13])

Information and data literacy	1.1 Browsing, searching and filtering data, information and digital content 1.2 Evaluating data, information and digital content 1.3 Managing data, information and digital content
Communication and collaboration	2.1 Interacting through digital technologies 2.2 Sharing information and content through digital technologies 2.3 Engaging in citizenship through digital technologies 2.4 Collaborating through digital technologies 2.5 Netiquette 2.6 Managing digital identity
Digital content creation	3.1 Developing digital content 3.2 Integrating and re-elaborating digital content 3.3 Copyright and licenses 3.4 Programming
Safety	4.1 Protecting devices 4.2 Protecting personal data and privacy 4.3 Protecting health and well-being 4.4 Protecting the environment
Problem solving	5.1 Solving technical problems 5.2 Identifying needs and technological responses 5.3 Creatively using digital technologies 5.4 Identifying digital competence gaps

The push for innovation in training activities and the definition of technological and digital skills have undergone rapid acceleration due to the COVID-19 pandemic crisis, which necessitated changes in the provision of services [14, 15]. The pandemic emergency has forced many higher education and degree courses to adapt and, specifically, to find new solutions to carry out experience-based training activities to guarantee the expected outgoing skills through online or hybrid methods [16–19]. After the phase of emergency remote teaching, many investigations have highlighted the effect of the pandemic on higher education; they have suggested, among other things, rethinking the technological and digital skills of trainee teachers as well as the positive feedback from students regarding virtual or hybrid workshops [20, 21]. Gaebel and colleagues [14] pointed out that hybrid learning and teaching.

> *implies physical classroom learning in combination with online attendance: whereas some students attend in the classroom, others attend at the same time remotely online, out of choice, or a condition preventing them from physical attendance.* (p. 8)

Although, during the COVID-19 pandemic, a hybrid solution was a means to reduce class sizes as a sanitary precaution, it is also increasingly used as a more sophisticated and complex approach combining different *learning approaches, such as (…) a flexible combination of different learning modes to enhance the learning experience, to better serve students and give them choice.* (p. 8)

Some research has investigated the participation of students enrolled in university adapted courses, taking into account the attendance, classroom interaction, assignment of tasks and use of e-learning platforms etc. [22–24]. It has been found that:

- Online education has been successfully implemented and the discipline content has been understood by students but that student interaction during the meeting class is low [22];
- Students' intention to participate is mediated more by the perceived usefulness and perceived ease of use of the e-learning systems than by the support received from the educational institution [23];
- A positive perception of the learning experience is mediated by the teaching method and the use of easily accessible and flexible online software [23];
- Regarding the students' satisfaction, for students who had sufficient hardware and software resources, the online approach presented few barriers; students who were subject to the digital divide instead had to integrate other support [24].

Concerning students' perception of online learning during and after the pandemic, their preference is for the face-to-face mode; however, aspects such as the ease of access to content and the flexibility of learning environments mean that online learning is perceived as viable in the future.

2 Background, Objectives and Participants in the Study

In the academic year 2021/22, the workshops of the master's degree course in Primary Education still took place in mixed mode—in person and online—due to the last phase of the COVID pandemic. The master's degree in "Primary Education Sciences" at the University of Bergamo provides 23 workshops distributed across four learning areas—basic pedagogical and sociological disciplines, school knowledge, school inclusion and teaching technologies. The "Educational Technology Workshop' (three university credits) is held in the fourth year of the course, in the first and second semesters. At the end of the course, the students are asked to master multimedia tools to support digital storytelling: they design an educational digital storytelling project reflecting on the theme, the target audience and the objective of communication (see *Communication and Collaboration* in DigComp2.2); write a storyboard thinking about narrative and technical solutions to communicate the contents related to the project effectively; search for and select information and digital multimedia resources (*Information and Data Literacy*); gain awareness of the educational purposes and of the copyright on texts, voices, images and videos (*Digital Content Creation*); and create digital storytelling by combining technical skills and creative solutions (*Problem Solving*).

Within the "Educational Technology Workshop," students are asked to produce digital storytelling (DTS) about 5 min long, combining images, audio, narration, musical commentary and possibly video. The structured production activity (see Table 3) [25] is inspired by the "Powerful Tools for Teaching and Learning: DST" course on the Coursera platform held by B. Robin and S. McNeil of the University of Houston [26].

Table 3. Phases and actions of the DTS production "Educational Technology Workshop"

Phases	Actions
1. Choice of topic and objectives	Introduction of DST—basic elements Choice of topic and educational objective Drafting and uploading of a summary document to the e-learning platform
2. Script drafting and storyboard creation	Focusing on an effective plot and choice of images Drafting the script Evaluation of stories by at least three colleagues
3. Recording the story	Presentation of digital devices for recording and post-production Recording the audio track Platform evaluation of (at least) three colleagues' scripts
4. Integration of multiple media sources in DST	Combining text, images, audio and video in a multimedia editing environment Realizing the final product Web publishing
5. Final peer assessment	Evaluation of at least three films of colleagues

In such a context, a descriptive study was conducted with the general purpose of determining the student teachers' learning experience, in person or online, during the workshop. The study was structured in two phases: in the first, the "attendance" variable (in person or online) was analyzed using quantitative data; in the second, the same variable was analyzed but on the basis of qualitative data [27]. The objectives of the study were:

a. To describe the student teachers' perception of the learning experience gained in person or online during the workshop;
b. To verify whether the method of attending—in person/online—influenced the student teachers' perception regarding the strengthening of their digital skills.

Table 4 shows the characteristics of the student teacher population involved—chronological age (Age) and length of service as a teacher (Length of service)—as well as the modality of participation in the workshop (Attendance). The following are reported: the total answers—number (second column) and percentage (third column)—and the responses divided according to the modality of participation in the workshop—face to face (fourth column) and online (fifth column).

Table 4. Socio-professional characteristics and attendance of the student teachers involved

Characteristics	Tot. n. 102	Tot. %	In person*	Online**
Age (years)				
21–30	**77**	**75.49%**	14 (100%)	63 (71.59%)
31–40	19	18.63%	0 (0.00%)	19 (21.59%)
41–50	6	5.88%	0 (0.00%)	6 (6.82%)
51–60	0	0.00%	0 (0.00%)	0 (0.00%)
Over 60	0	0.00%	0 (0.00%)	0 (0.00%)
Length of service (years)				
0–1	**52**	**50.98%**	14 (100%)	38 (43.18%)
2–5	40	39.22%	0 (0.00%)	40 (45.45%)
6–10	8	7.84%	0 (0.00%)	8 (9.09%)
Over 10	2	1.96%	0 (0.00%)	2 (2.27%)
Attendance				
In person*	14	13.73%		
Online**	**88**	**86.27%**		

With reference to the student teachers involved, 75.49% (n. 77) belong to the age group 21–30 ($\mu = 26$ years), 50.98% (n. 52) have about 1 year of service at the school and 86.27% participated in the workshop in the online mode. Specifically, all 14 student teachers who attended face to face were between 21 and 30 years old and had 1 year of service. Most of the students who attended online (n. 88) were between 21 and 30 years old (n. 63); they had 1 year (n. 38) and between 2 and 5 years (n. 40) of service.

3 Data Collection and Data Analysis

3.1 Data Collection

An "ad hoc" questionnaire was created for data collection. It was divided into three parts: a. socio-professional information; b. perceptions of the "Educational Technology Workshop" (questions 5, 6 and 7); and c. reflections on digital storytelling.

The analysis presented below was conducted on the answers to the questions in the second area:

- Which of the following teaching methods do you think have mainly characterized the "Educational Technology Workshop"? (question 5);
- Which of the following educational activities of the degree course do you think are more connected to the "Educational Technology Workshop"? (question 6);
- How much do you think the "Educational Technology Workshop" has strengthened your digital skills? (question 7).

The questionnaire was administered to all the attending student teachers (n. tot. 150); 102 of them answered the questionnaire (68%). The student teachers were left free to answer the questionnaire without any constraint or link with their participation in the workshop. The administration took place through online forms at the end of the workshop activities.

3.2 Data Analysis

The statistical analysis of the data matrix was conducted on two levels:

- A description of the answers to questions 5–7 (see Tables 5, 6 and 7);
- A study of the correlation between "attendance modality" (in person or online) and the answer to question 7—"perception of the strengthening of digital skills" (see Table 7).

Table 3 reports the answers to questions 5–7. Table 4 presents the difference between the answers of student teachers who attended in person and the answers of those who attended online.

Table 5. Answers to questions 5–7 (total %)

Questions	N. (Tot. 102)	%
Prevailing teaching methods (question 5)		
lesson/seminar	6	5.88%
alternation lesson/exercises	**92**	**90.20%**
exercises	4	3.92%
Main connection with (question 6)		
lecture	16	15.69%
other workshops	18	17.65%
practicum	**68**	**66.67%**
Strengthening of digital skills (question 7)		
very low	0	0.00%
low	8	7.84%
medium	34	33.33%
high	**49**	**48.04%**
very high	11	10.78%

A simple correlational analysis was carried out between the variable "attendance" and the students' perception of the influence of the workshop on strengthening their digital skills (answers to question 7) to evaluate the existence of a possible relationship. Table 5 shows the total average of the responses and the averages divided into attendees "in person" and "online" (second column), the standard deviations (third column) and the correlation of the total answers with the variable "attendance" (fourth column).

Table 6. Answers to questions 5–7 Difference between student teachers attending in person and online

Questions	In person, n. and % (tot. 14)	Online, n. and % (tot. 88)
Prevailing teaching methods (question 5)		
lesson/seminar	0 (0.00%)	6 (6.82%)
alternation lesson/exercises	**13 (92.86%)**	**79 (89.77%)**
exercises	1 (7.14%)	3 (3.41%)
Main connection with (question 6)		
lecture	1 (7.14%)	15 (17.05%)
other workshop	3 (21.43%)	15 (17.05%)
practicum	**10 (71.43%)**	**58 (65.91%)**
Strengthening of digital skills (question 7)		
very low	0 (0.00 %)	0 (0.00%)
low	0 (0.00%)	8 (9.09%)
medium	3 (21.43%)	31 (35.23%)
high	**9 (64.29%)**	**40 (45.45%)**
very high	2 (14.29%)	9 (10.23%)

Table 7. Answers to question 7 Average, standard deviation and correlation with "attendance"

			Attendance
Strengthening of digital skills (question 7)	3.61 (μ) tot 3.92 (μ) in person 3.56 (μ) online	0.78 (σ) tot 0.79 (σ) in person 0.61 (σ) online	0.15 (ρ)

4 Results, Limitation and Discussion

The descriptive statistical analysis allows us to infer some interesting differences between student teachers who attended in person and online:

- *Prevailing teaching methods* (question 5): Although, in general, the main perceptions of student teachers are about the alternation between lessons and seminars/exercises (Table 5—90.20%), online-attending student teachers perceive the lesson–seminar teaching methods better (Table 6—6.82%) than those attending in person (Table 6—0.00%);
- *Main connection with other training activities* (question 6): While, in general, student teachers perceive the Educational Technology Workshop as mainly connected with practicum (Table 5–66.67%), student teachers attending online perceive the connections with lectures and other workshops (Table 6—17.05%) more than those attending in person (Table 6—7.14%, 21.43%);

- *Strengthening of digital skills* (question 7): The students' perception regarding the influence of the "Educational Technology Workshop" on strengthening their digital skills is high in general (Table 5—48.04%); such a perception is, however, slightly lower in student teachers who attended online (Table 6—45.45%), while, on the contrary, it increases in student teachers who attended in person (Table 6—64.29%).

The statistical study conducted on the answers to question 7 found a total average of 3.61 (μ), with respect to a range from 1 to 5, low dispersion ($\sigma = 0.78$) as well as a low correlation ($\rho = 0.15$) with respect to the type of attendance (in person or online) (Table 7).

The descriptive statistical analysis allows us to detect some differences between the perceptions of student teachers who attended the "Educational Technology Workshop" in person and those of their classmates who attended online as regards the following:

- *Prevailing teaching methods*—The student teachers who attended in person grasped the alternation between lessons and exercises better; the student teachers who attended online, conversely, grasped the transmissive aspect of the workshop meetings more;
- *Connection with other training activities of the degree course*—The student teachers who attended online found more connections with other lessons and workshops than their colleagues who attended in person.

A simple correlational analysis, instead, did not find a direct relationship between the way in which student teachers participated in the Educational Technology Workshop and their perception of its influence on their digital skills.

Therefore, considering the objectives of this study:

- The student teachers' perception of the learning experience during the Educational Technology Workshop differs in relation to whether the participation was in person or online, especially regarding the *prevailing teaching methods* and the *connection with other training activities* of the degree course;
- The modality of attendance—in person/online—does not influence the student teachers' perception of their digital skills after having participated in the workshop. This correlational hypothesis will therefore have to be rechecked with a larger sample with homogeneous socio-professional characteristics; it should be noted that (see Table 4) the student teachers who attended online had a higher average age and length of service. This may have influenced their perception of their digital skills and its relationship with the "Educational Technology Workshop."

5 Conclusion

This study confirms the results of other similar studies that have investigated the positive perception of higher education students regarding training activities adapted online after the COVID-19 pandemic [22, 23]. Such a positive perception concerns teaching methods and is related to the ease of access and work flexibility favored by technological means such as online platforms. The study presented specifically investigated the perception of student teachers regarding experiential-based training activities, such as the workshop—a mandatory and indispensable activity within the degree course for teaching in primary school in Italy. It also investigated the perception of the student teachers themselves regarding their own digital skills—skills that are now strongly required of teachers at all school levels.

It emerged that student teachers who attended online are slightly more sensitive to the teaching methods through which the workshop is carried out and to the integration of the workshop with the other training activities of the entire degree course. The different perception that students have of the learning experience based on the modality of attendance is an aspect that program managers must take into account—for example. Resorting with more awareness and conviction to integrated or mixed methods of delivering courses.

The second phase of the study was conducted on qualitative data and further studies should investigate the reason for such sensitivity of students participating online, whether it depends on the socio-professional characteristics of the sample or on the online setting that favors the exercise of digital skills. Pending future evidence, we should not overlook such sensitivity. More generally, we should not neglect what emergency remote teaching has taught on the level of experimentation in mixed or hybrid learning environments [14, 22, 23]:

> *In order to build a post-COVID-19 university education, i.e., one that is increasingly digital and sustainable, it is essential to learn from these years of health crisis.* [27]

Conversely, the data on the low correlation between the attendance method and the perception of personal digital skills after participation in the workshop allow us to hypothesize that the origin of this perception must be sought elsewhere and that it is not influenced by the conditions in which the experience of learning takes place. This, if confirmed with wider studies, will be valuable above all for course designers who train teachers in digital skills and others.

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Intrinsic Motivation for Social Media Literacy, a Look into the Narrative Scripts

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Abstract. Social media embodies the idyllic representation of the information society providing users opportunities to connect and communicate. Likewise, it can represent humanity's worst nightmare with a plethora of negative phenomena. Different forms of media literacy interventions have been designed as preventative tools to counteract the negative phenomena of social media. One such approach, the narrative scripts, sees the integration of a social media intervention within a controlled social media platform. With an importance to design engaging educational tools to get learners attention without limiting the educational deliverables, the narrative scripts approach sees the implementation of gamifying elements to help deliver the learning material and motivate learners to participate. To assess the effectiveness of the proposed motivational properties of the narrative scripts, a descriptive exploratory study was designed. In total 124 adolescents participated in a social media literacy workshop powered by the narrative scripts. During the workshop students completed missions assigned by a virtual learning companion and participated in collaborative learning activities. To measure the motivation levels of the students, the Intrinsic Motivation Inventory was applied. Results demonstrate that adolescents found the narrative scripts an interesting and enjoyable activity. Qualitative analysis supported the findings with adolescents describing the activities as dynamic and entertaining. The results from this study provide insights towards the motivational aspects of the narrative scripts as a social media intervention tool.

Keywords: social media · digital skills · intrinsic motivation · self-protection skills · CSCL scripts · counter-narratives

1 Introduction

Social media is a growing environment for daily socialization [1]. Post pandemic reports confirm that at least in the developed countries, people easily combine their traditional communication, education and work habits with the support of social media platforms [2]. Social media epitomizes the idyllic representation of the information society with borderless experiences of collaboration, creation and social engagement [3]. Likewise, it

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represents humanity's worst nightmare and fears with misinformation and manipulation coexisting in the digital landscape [4, 5].

Social media can be an unsafe environment for children and adolescents [6]. To this respect, media literacy has been addressed as a preventive tool to raise awareness of the risks and threats present in the social media [7]. Not all media literacy interventions meet the same approach nor apply the same resources. While some interventions focus on a protective approach (i.e. monitoring children's consumption and exposure) others promote inoculation as a way to enhance self-defense mechanisms such as critical thinking [8]. Whatever the approach is, different scholars and practitioners agree on the importance of designing educational interventions that motivate young users to observe the nuances of media and technology [9, 10]. The grounds of motivational theories offer the possibility to design pedagogical activities adapted to the new media environment and young people's interests [11, 12].

As an advocate of critical thinking, digital literacy provides children and adolescents with a curriculum that equips them to better understand, read and use the media. It, therefore targets, designing programs that not solely tackle the reduction of social media use but also promote the inoculation of coping skills and defenses [9]. One exemplary program is the one conducted by the Courage Project, media education research focused to develop Virtual Learning Companions to educate young social media users [12]. The Courage Project encompasses different research approaches and media education initiatives. One of the key elements is the development and implementation of Narrative Scripts [13].

Narrative Scripts (NS) target the inoculation of social media awareness by focusing on training learners' critical thinking and coping skills. Among the different features that make NS a potentially effective learning resource, is the implementation of gamifying elements such as storytelling, roleplay and real case scenarios [14]. Although the narrative approach has been quite discussed in Media Education [15–18], and the related literacies (i.e. health, human rights, gender), the exploration of NS in computer situated scenarios has been discussed to a lesser extent in the current research. This study therefore aimed to analyze the effect of NS on students' learning motivation. Specifically, we examine "how does NS affect students' intrinsic motivation to learn about social media and enhance awareness?

The structure of the paper is as follows. Section 2 presents our perspective of intrinsic motivation in the design of learning activities. Section 3 describes the implementation of a NS. The method and the results of the study are reported in Sects. 4 and 5, respectively.

2 Intrinsic Motivation and the Design of Learning Activities

The Courage project's approach includes the use of a NS to teach about social media using a social media environment and all its characteristics (chat, post-like pictures, follow profiles, etc.) together with an embedded learning module where the narrative content is presented. As the recent literature shows, teenagers are highly active and engaged in social media [19, 20], but the design of learning activities, materials and a whole narrative experience to teach them needs also to be engaging. Motivational experiences emerge not from single design elements, but from the total environment-system [21].

One of our main interests was that the NS were motivating. We wanted the students to feel that they were learning in a playful way. In order to achieve this, we followed the self-determination theory (SDT), a theory to understand human motivation in general contexts. It states that human motivation is situated in a continuum between extrinsic motivation: doing something due to a superable outcome such as pressure or extrinsic rewards, and intrinsic motivation: the pursuit of an activity because it is inherently interesting or enjoyable [22]. Examples of applications that had strong components of on intrinsic motivation in their design are games with a purpose (GWAP) [23] and citizen science [24].

Although both types of motivation promote performance gains [25] intrinsic motivation has been credited for improving psychological well-being, learning outcomes, enhancing creativity and extending the quality of effort that people put into a given task [25, 26]. According to the SDT, activities that increase intrinsic motivation need to satisfy the basic human needs of competence, autonomy, and relatedness [26].

Competence is related to the extent of one's own actions as the cause of desired consequences in one's environment. Direct and positive feedback is a very important factor in this aspect. Students need to see that their actions, opinions or answers matter and have an impact. Autonomy is the feeling created by a self-determined behavior rather than controlled by some external source [26]. Although some activities can be scripted, what happens inside the activities needs to give the students a feeling of real autonomy. Relatedness refers to one's role within a social community, the belief that others value an individual and care about them.

Contexts and activities that support people's perceptions of having agency, freedom, emotional support and connection have been shown consistently in SDT research to result in high quality, self-directed, intrinsic motivation [27]. For the design of the NS activities the three aspects of competence, autonomy and relatedness were taken into account, developing learning activities that made the students the central point of a narrative where they help to build a new social network by giving their opinion as experts and solving problematic situations presented by different characters while at the same time learning about social media concepts.

3 Narrative Scripts (NS)

The NS introduce an innovative approach towards social media education with the integration of collaborative learning elements and narrative pedagogy strategies within an educational social media platform (Table 1) [14]. As part of this pedagogical approach, students can easily interact between them as they would normally do in any social media while they receive social media guidance with the support of a virtual companion. Chatbots have been used in different pedagogical interventions showing good results in terms of engagement [28, 29]. The chatbot performs as a platform host who introduces the student to a set of social media stories deployed as challenges (missions). The main idea behind this pedagogical strategy is to create an environment where students can easily learn about social media through social media, promoting the inoculation of critical thinking and self-protection skills while observing and evaluating real social media scenarios (i.e. social media addiction, cyberbullying, profile curation). The use of NS not only gives educators the opportunity to base social media teaching/learning on social media scenarios but also to dynamically defeat the dominant viewpoints with the introduction of counter-narratives [30]. From this perspective, students are urged to play an ordinary role in social media, and genuinely interact with the NS characters to subsequently be questioned about their responses or decisions. Eventually, students are intuitively invited to play a different role or scenario.

Table 1. Pedagogical strategies in narrative scripts [14] and implementation used in the study

Narrative - Storytelling	
Strategy: Provide students with motivating, engaging, authentic scenarios suited to their personal experiences, making the content seem important and valuable [31]. Storytelling provides a way for students to generate new ideas and organize their knowledge, while at the same time helps the organization of content in a modular way: chapters, missions, tasks. Additionally, students that successfully complete the different tasks gain a sense of competence and confidence	**Implementation:** In our study students took part in a compelling story where they helped the design of a new social network called Instareal. They received different missions where they had to explore different social media phenomena, learning materials and give their own opinions. During these missions students explore different types of multimedia content (audios, videos, photos, web content)
Narrative - Counter-narratives	
Strategy: Expose students to opposite views about concepts or realities, in order to challenge previously made assumptions, generating learning from awareness and new perspectives	**Implementation:** Inside Instareal students interact with different characters that show them conflictive situations and ask for the students' help to solve their problems. Students could express their advice to the characters using a chat-like interphase where they could freely express their opinion. This gave the students a very good sense of autonomy
Scripting - Scaffolding	
Strategy: Structure the learning method through small, manageable steps for students to complete across a learning path that is aligned with their previous knowledge and has been designed to lead them to expected learning outcomes [32]	**Implementation:** The learning activities were organized in missions-tasks that were given to the students by the different characters, each mission corresponded to a topic and had a set of activities that students need to accomplish in order to pass to the following one

(*continued*)

Table 1. (*continued*)

Narrative - Storytelling	
Scripting - Structuring social interaction	
Strategy: Define and structure a collaborative learning flow (group formation, sequence of tasks, role rotation, etc.) in Computer supported collaborative activities (CSCL) to facilitate the triggering of desired social interactions leading to fruitful learning. Conversation with rich argumentation is one of these key social interactions as it promotes productive ways of thinking, conceptual change, and problem-solving [14]	**Implementation:** As part of the missions inside Instareal students participated in collaborative activities where in groups had to analyze situations related to social media phenomena and reach a conclusion. Additionally, Inside Instareal students created a social media profile and were able to perform all the actions of the regular social networks (publish pictures, like, comment) interacting with their classmates and their content

There are currently four types of tasks supported by the NS. These include: free roaming inside the social network, guided roaming to complete missions visiting specific profiles, group tasks to propose the solution to a situation in a CSCL activity and playing mini-games that provide social media literacy in a dynamic/ludic way.

Free Roaming. Uses the pedagogical strategy of social interaction: during these activities students are encouraged to roam within the social media platform and interact with preloaded content without any instructions or restrictions.

Guided Roaming. Uses the pedagogical strategies of narrative-storytelling, scaffolding and counter-narratives: during these activities students are instructed to engage with fictional curated profiles with the aim to analyze them and reflect upon them. At the current iteration, four characters have been designed to guide students through missions to teach them about social media related concepts. The design involved the use of storytelling, the fabrication of images and videos, and the curation of character profiles (see Fig. 1).

Group Tasks. Uses the pedagogical strategy of Scripting - Structuring social interaction: the current version of the NS platform supports the integration of two CSCL tools that allow students to collaborate between them (Fig. 2). These tools have been designed following the collaborative learning flow patterns of pyramid and jigsaw [33]. Specifically for the pyramid CLFP the educational platform PyramidApp was integrated. In PyramidApp [34] students help each other to solve a question in groups. The software organizes the groups equitatively and provides a web interface for the different phases (individual submission, rating phase, collaborative answer). For the jigsaw CLFP, the educational platform EthicsApp was integrated. In the EthicsApp [35] students are grouped in experts groups and are asked to reflect on a question dedicated to their role. In the first phase using the chat inside the EthicsApp the group members present their ideas. During the next phase, the jigsaw phase, the app creates groups with experts on the different pieces of information so they can share their knowledge and arrive at a conclusion on the discussed topic.

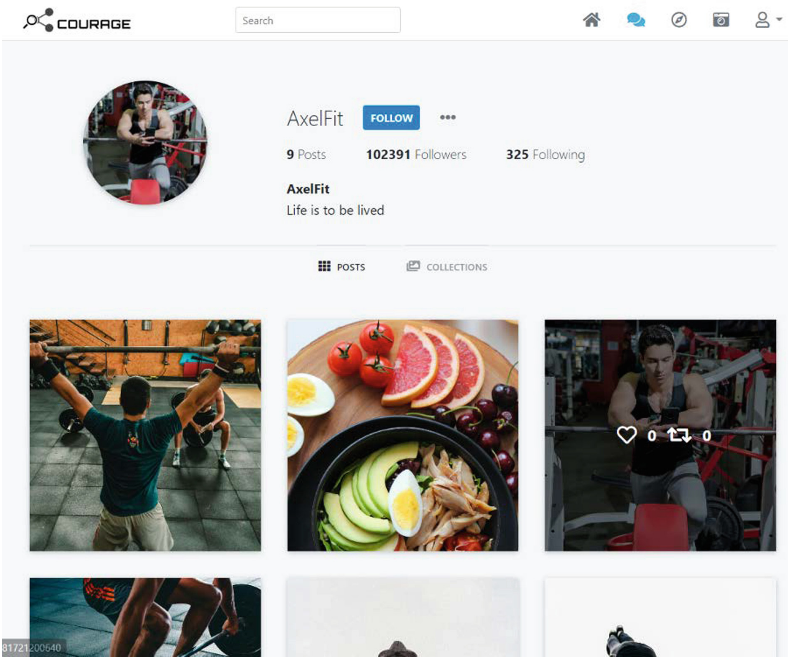

Fig. 1. Influencer profile, photos taken from unsplash.com and pexels.com

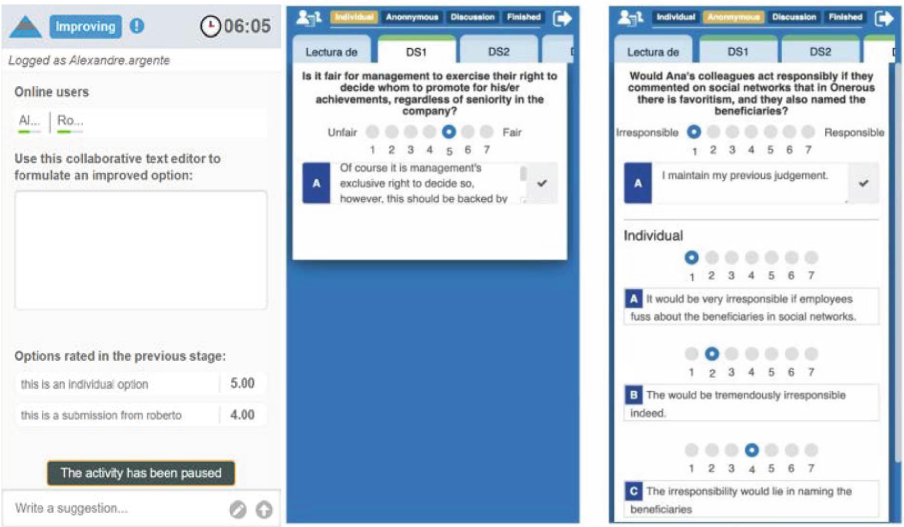

Fig. 2. Collaborative activities PyramidApp (left) EthicsApp (center, right)

Mini-games. Uses the pedagogical strategy of scaffolding: a set of mini-games is also implemented within the platform to provide students with a refreshing view of the missions at the end of NS. Figure 3 exemplifies the interface of some of the minigames for the topics of social media addiction, cyberbullying and digital footprint (Fig. 3). Contrary to the traditional teaching approach, the use of minigames is aimed to reinforce students' learning by engaging them in the evaluation of scenarios and the application of concepts rather than instruction or memorization of concepts.

Fig. 3. Example of minigames implemented

All currently prepared tasks (four) produce outcomes that adapt learners' experience [30]. For example, during roaming tasks students leave a footprint of their preferred influencers which feeds their dominant narrative. This data is collected and later used by the system to offer the user a different experience, to target the dominant viewpoints by offering a counternarrative (also provided by the learning materials). Moreover, data related to the students' engagement during the activities is also generated. Variables like the answer text, response times, progress and participation in the collaborative activities could be used to measure the students' engagement and provide more levels of personalization to the NS.

To conclude, the different elements of the NS have been carefully designed to promote the three aspects of competence, autonomy and relatedness to the learners. To assess to what extent this has been achieved, this study aims to analyze the narrative scripts' effect on students' motivation in the context of social media.

4 Method

4.1 Study Design and Participants

We designed a descriptive exploratory study to analyze how NS affects students' motivation to learn about social media. This study utilizes data gathered during a Media Literacy intervention in a high school from Barcelona during the first term of 2022. The analyzed sample consists of 124 participants (n = 124; 67 male, 53 female, and 4 undefined; Ages 15 to 19, mean age = 16.8, SD = 1.14). The data was collected during the fourth session of a 6-day workshop conducted in a regular class schedule at students' ordinary classrooms. As part of the research protocol, participants and their families were informed about the purpose of Courage Media Literacy workshops and consented to participate by signing an information sheet.

4.2 Instruments and Measurements

To measure the effect of NS on students' learning motivation, this study supported a mixed method approach based on quantitative and qualitative measurement.

As part of the quantitative measurement, the Intrinsic Motivation Inventory (IMI) was employed [36]. The IMI is a multidimensional measurement device intended to assess participants' subjective experience related to a target activity in laboratory experiments. It has been used in several experiments related to intrinsic motivation and self-regulation (e.g., [37–42]). The instrument assesses participants interest/enjoyment, perceived competence, perceived choice, felt pressure and tension while performing a given activity, creating four subscale scores. (Table 2).

Table 2. Intrinsic Motivation items observed in the present study

Interest/Enjoyment	I would describe this activity as very interesting
	I enjoyed doing this activity very much
	I thought this was a boring activity
Perceived competence	I think I am pretty good at this activity
	I think I did pretty well at this activity, compared to other students
	After working at this activity for a while, I felt pretty competent
Perceived choice	I felt I could do what I want during this activity
	I felt like I had to do this
	I believe I had some choice about doing this activity
Perceived tension	I felt very tense while doing this activity
	I was very relaxed in doing these
	I felt pressured while doing these

The interest/enjoyment subscale is considered the most representative self-report measure of intrinsic motivation. However, the perceived choice and perceived competence concepts are also theorized to be positive predictors of both self-report and behavioral measures of intrinsic motivation, and pressure/tension is theorized to be a negative predictor of intrinsic motivation.

This study considered the assessment of four dimensions to measure intrinsic motivation: interest/enjoyment, perceived competence, perceived choice, felt pressure and tension. The instrument uses a seven-point Likert scale ranging from not at all true (1) to very true (7). Additionally, a qualitative open question was used to explore students' impressions and thoughts about the NS. Specifically, what features they enjoyed the most and what others they would change in future activities. Student's responses were exported and qualitatively coded for their analysis.

4.3 Procedure

The present study was based on a situated learning experience: a workshop scenario. Workshop learning scenarios are formal instruction approaches to genuinely produce action-research [43]; that is for researchers, the ability to observe and analyze learning experiences in the natural settings while for participants the opportunity to perform in an ordinary way [44].

During a 6-session workshop, students participated in the media literacy workshop "The Social Media of the Future" designed by experts and technicians of the COURAGE project. As part of the workshop curriculum, students revised some topics such as social media addiction, digital footprint, fear of missing out (FoMO), etc. Each session began with a quick presentation from the instructor, some free roaming time inside the platform and the narrative script task. Depending on the session, narrative scripts tasks featured one or more CSCL activities (i.e. pyramid app, jigsaw, etc.). Data concerning the evaluation of students' motivation was collected during the fifth session as students answered the Intrinsic Motivation Inventory questionnaire and the qualitative question.

5 Results

5.1 Students' Intrinsic Motivation

Table 3 displays the descriptive statistics for the inventory items. According to the recorded values, participant students mostly reported acceptable values of agreement by rating the educational setting (narrative scripts) as an interesting and enjoyable activity (items 1 and 2). Aligned with this, a large percentage of participants also agreed that NS promoted their self-confidence and competence (items 4, 5 and 6). Conversely, to the optimistic results of enjoyment and competence, perceived choice showed contrasting results as some participants reported, for instance, to feel like they had to do the task (item 8). Items evaluating tension (10 and 12), on the other hand, reported the lowest level of agreement.

Table 3. Reported levels of agreement for measured items

Items	Slightly True % (N)	True % (N)	Very True % (N)	Mean	SD
1. I would describe this activity as very interesting	7,3 (9)	65,3 (81)	27,4 (34)	4,63	1,40
2. I enjoyed doing this activity very much	11,3 (14)	65,3 (81)	23,4 (29)	4,34	1,45
3. I thought this was a boring activity	29,8 (37)	55,6 (69)	14,5 (18)	3,76	1,64
4. I think I am pretty good at this activity	9,7 (12)	68,5 (85)	21,8 (27)	4,37	1,47
5. I think I did pretty well at this activity, compared to other students	13,7 (17)	74,2 (92)	12,1 (15)	3,96	1,39

(*continued*)

Table 3. (*continued*)

Items	Slightly True % (N)	True % (N)	Very True % (N)	Mean	SD
6. After working at this activity for awhile, I felt pretty competent	18,5 (23)	67,7 (84)	13,7 (17)	3,86	1,59
7. I felt I could do what I want during this activity	17,7 (22)	62,9 (78)	19,4 (24)	3,99	1,60
8. I felt like I had to do this	40.3 (50)	54,0 (67)	5,6 (7)	4,85	1,47
9. I believe I had some choice about doing this activity	7,3 (9)	50,8 (63)	41,9 (52)	4,81	1,61
10. I felt very tense while doing this activity	69,4 (86)	25,0 (31)	5,6 (7)	2,21	1,51
11. I was very relaxed in doing these	7,3 (9)	51,6 (64)	41,1 (51)	5,03	1,63
12. I felt pressured while doing these	60,5 (75)	34,7 (43)	4,8 (6)	2,39	1,63

The measurement of intrinsic motivation inventory reported the highest mean values for the variable interest/enjoyment ($M = 4.4$). In contrast, pressure and tension reported the lowest mean value ($M = 2.52$) (Figure x). Zero order correlations (see Table 4) reported positive association for Interest/Enjoyment and Perceived Competence ($r = .47$, $p < .00$); also, for Interest/Enjoyment and Perceived Choice ($r = .35$, $p < .00$). Perceived Competence was also positively associated with Perceived Choice ($r = .38$, $p < .00$). By the contrary, pressure/tension was negatively correlated with aforementioned variables. In all cases, correlations were mostly moderate.

Table 4. Zero order correlations for the operationalized inventory items

	Interest/Enjoyment	Perceived Competence	Perceived Choice	Pressure/Tension
Interest/Enjoyment	1			
Perceived Competence	,479**			
	0			
Perceived Choice	,358**	,385**		
	0	0		
Pressure/Tension	−,280**	−0,023	−,220*	1
	0,002	0,796	0,014	

5.2 Qualitative Analysis

A qualitative analysis of the open question identified the motivational aspects related to the use of NS to enhance social media awareness. Among these aspects, participants reported having enjoyed the tasks assigned through the NS as a way of reflecting and practicing what they have reviewed along the social media literacy module.

Consistent with this, most participants affirmed that they were satisfied with the format of the activities and would not change anything. In fact, while evaluating the teaching instruction, participants rated both the sessions and the materials as "well designed". The collaborative activity, on its part, caused interest among the students given the context of the instruction (extracurricular activity).

Regarding the less motivational aspects, some participants brought to discussion that the topic broadened in the NS was not very novel; likewise, some other participants underlined the lack of freedom to interact with the chatbot as sometimes the interaction remained as a programmed response that does not contribute more to students' interaction. Participants also argued that some activities should be more dynamic and less repetitive.

In general terms, the workshop was valued as a comfortable space for sharing points of view, as it allows the participants to freely express their opinions. Likewise, the participants felt motivated by the continuous evolution of the workshops; and they describe this evolution as the transition from "heavy and tedious" sessions to more dynamic and entertaining activities that generated greater interest and enjoyment. In summary, participants describe the workshop as a useful educational experience.

6 Conclusion

With an increasing importance to provide engaging educational tools to counteract the negative effects of social media, this study explored the design of the narrative scripts from a motivational approach. Results have shown that the NS can generate intrinsic motivation amongst learners. Specifically, it has shown a positive reaction from students in the areas of interest in the topic and engagement in educational activities. According to the qualitative observations, the use of NS may also contribute to improve students' confidence to interact with the content and share their opinion. We therefore conclude that the design of the NS provides an engaging educational experience to the students.

Future work should focus on improving the interactivity of the learning experience by adjusting the chatbot answers depending on the chat with the students, add more and varied minigames and multimedia content in order to diversify the task activities and observe new ways to measure the intrinsic motivation inside NS and collaborative activities. This could be achieved by studying the traces left by the students in the software logs.

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Online/Hybrid Course Design for Programming Languages in Engineering Education

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Abstract. In this study, we aim to propose a useful course design framework for undergraduate programming languages in hybrid learning environments. Hybrid learning environments are a means of delivering instructional content in that online educational materials and opportunities for interaction were combined with traditional classroom methods. We followed the Kemp Instructional Design Model to design the course. First, we defined the instructional problems. Second, we worked on the learning styles and needs of both students and teachers by utilizing questionnaires. We also analysed the existing course plans from five European countries. According to the course plan analysis, we have identified weekly topics, learning objectives, and related pedagogical approaches. Third, based on the data from the questionnaires and the course plan analysis, we made content analysis to determine the instructional objectives. Then, we sequenced the content, determined the instructional strategies, and designed the messages, by utilizing the content analysis. As a result of these steps, we developed a Course Plan Template. The template has features especially in terms of instructional strategy issues which are closely related to student-based learning approach such as feedback, gamification, and flipping the classroom. It is expected to be an effective course design for undergraduate programming languages in hybrid learning environments.

Keywords: Hybrid Learning · Programming Languages · Course Design

1 Introduction

Educational technology, particularly online/hybrid education, could have an important role in managing Higher Education post-pandemic crisis. Shuttered campuses have

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turned to distance learning, with educators forced to adopt new technology for teaching and to figure out how to turn what is often hands-on education into private practice. Changes in students' learning environment have motivated universities and educators to reconsider pedagogy and teaching methods. Using novel pedagogical achievements for educators and applying new technologies in classrooms are very important requirements. As educators become more familiar with digital technologies for teaching and learning, pedagogical responses and strategies are emerging. Now, professors need pedagogical practices for online education and integrating classrooms under the generic term of hybrid learning. It is another emerging teaching and learning environment where classroom time is reduced but not eliminated, with substantial time being used for online/hybrid learning.

Hybrid learning environments are a means of delivering instructional content in that online educational materials and opportunities for interaction were combined with traditional classroom methods. Hybrid learning environments give students the opportunity to work in an environment enriched with digital learning tools, and to support the student-based learning approach. Student-based learning approach promotes engagement to make students active learners via various ways such as interactivity, feedback, etc.

Researchers identified feedback as an activity for promoting effective online learning and more so creating the environment for teacher-student teaching and learning interaction [1]. Designing and implementing feedback in blended learning mode/hybrid modes, feedback plays the role of positive reinforcement of student learning. It should be appreciated that in hybrid or blended modes feedback needs to specifically be designed to meet each learning setting and also the integral (hybrid/blended) options. In this context, both the traditional written and virtual interactive feedback approaches come in handy for teachers to consider [2]. Consequently, learning feedback in hybrid learning settings could be operationalised by adapting some of these approaches: i) Text comments - with hyperlinks to reach the recipients (in the case of virtual environments), ii) on interactive platforms use the "like" function to should approval or good work done, iii) use audio to offer comments and further remedial directives, iv) similar video could be an option, v) use rubrics as a datum to offer bases to compare performance with, vi) automated feedback could be used at the online interactive mode of the hybrid learning, vii) using the streaming environment of the learning system to organise dialogues and general feedback about student performances, interactive sites automated feedback methods are used viii) use peer feedback as an approach to offer students learning feedback and x) use emojis and images to accentuate students' best practices, efforts, and progress; these should be seen as providing motivation to learners [3]. Indeed, in the quest to integrate feedback in the teaching and learning process, the overarching objective should be for student learning progress and achievement.

Some instructional strategies, on the other hand, like gamification and flipping the classroom, have an important role in supporting active learning. Education is one of the major fields in which gamification has been applied and investigated [4]. Studies have revealed that the application of game elements in hybrid learning environments increases productivity, effectiveness, motivation, and participation by providing students with a flexible environment that requires cooperative, problem-based learning; encourages active participation; it is student centred and therefore increases students' motivation [5]. A recent study published by Sailer and Sailer [6] concludes that gamification techniques like a gamified quiz with points and team leader boards within a flipped classroom situation can foster learning process performance that in turn facilitates the acquisition of application-oriented knowledge in higher education students. In addition, gamification feedback like experience points, levels and badges also increase students' engagement in training [7]. In well-designed gamified environments, students tend to dedicate more meaningful interactions with the learning process, as their efforts are promptly and effectively recognized [8].

Students, in flipped classrooms, are transformed from passive listeners into active learners [9]. In flipped learning, students are given "school work at home and home work at school" [10]. Students are expected to watch online tutorials, read texts, join online discussions and view online course materials at home [11]. When they come to school, students do debate, do presentations, do face-to-face discussions and practice their skills often guided by the teacher. With this approach, students have the chance to work on more personalized content since they will focus upon the parts they did not understand with the guidance of the teacher. As one of the advantages of flipped learning, there is more time for students to interact with each other and share information [12]. While they share information with each other, they also have the chance to learn from each other. Flipped learning is a useful method in hybrid learning environments to increase student-to-student interactivity and give students a space for individual learning experience.

Applied science and engineering courses, on the other hand, are complex and many students struggle with mastering the required competencies and skills. This is more visible, especially at the introductory level. Thus, an applied engineering course, such as a programming course, requires different strategies for educators to present content, interact with students, and assess course outcomes. A solid understanding of the learning process is essential to respond to the enormous global changes in higher education. The answers for better teaching and learning strategies require international collaborations from various disciplines and backgrounds that focus on the same problem. In that sense, the "Redesigning Introductory Computer Programming Using Innovative Online Modules" (RECOM) project, funded by the European Union within the Erasmus + KA226 program (Partnership for Digital Education Readiness) starting from June 2021, aims to bridge the gap between the existing national curricula related to engineering studies and the needs of "Covid" and "post-Covid" generation" students. It involves six Universities across Europe. In this study, we aim to propose a useful course design framework for undergraduate programming languages in hybrid learning environments.

2 Methods

As the design method, we followed the Kemp Instructional Design Model [13] to design the course (see Fig. 1). First, we defined the instructional problems. Second, we worked on the learning styles and needs of both students and teachers by utilizing questionnaires. The study used a questionnaire to elicit information from Bachelor level engineering students and from teachers. In all, 372 students sampled from 19 European countries participated in the data collection; whereas, 47 teachers from five European countries participated. We also analysed the existing course plans from five European countries. According to the course plan analysis, we have identified the weekly topics, learning objectives, and the related pedagogical approaches. Third, based on the data from the questionnaires and the course plan analysis, we made content analysis to determine the instructional objectives. Then, we sequenced the content, determined the instructional strategies, and designed the messages, by utilizing the content analysis. As a result of these steps, we developed a course plan template.

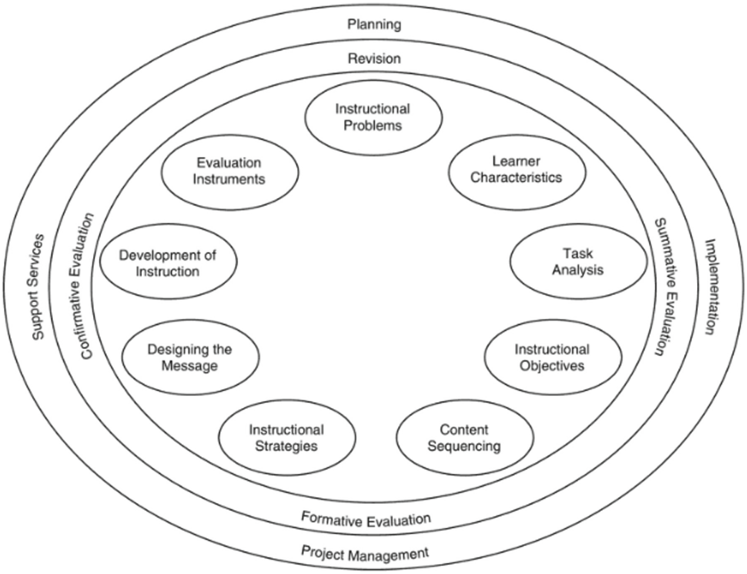


Fig. 1. Kemp Design Model [13].

This paper presents the course design process of a framework for undergraduate programming languages in hybrid learning environments. Thus, it covers the steps explained so far. However, the Kemp Design Model has other subsequent design steps that are development of instruction and evaluation instruments. Besides, the evaluation and implementation process have the steps of summative evaluation, formative evaluation, confirmative evaluation, and revision.

3 Results

Results from the questionnaire analysis showcased the major benefits of online programming language classes. Both students' and teacher's views show that: i) variety of learning materials, ii) self-organization of the curriculum, and iii) the possibility of teamwork were essential (see Fig. 2 and Fig. 3) and relevant factors for online learning. Precisely, 73% of students considered possibility to study in appropriate time and place as essential factor, whereas 68% considered availability as a relevant factor. Furthermore, with respect to possibility to read/repeat as many times, as needed in class

47% considered as essential. Whereas 33% of students considered variety of learning materials as essential (see Fig. 2).

On the part of the teachers, 64% considered the possibility to teach in appropriate time and place are essential whilst 47% had the view of variety of learning materials are essential. Yet, still 45% availability of the online learning environment as an essential factor for learning. (see Fig. 3).

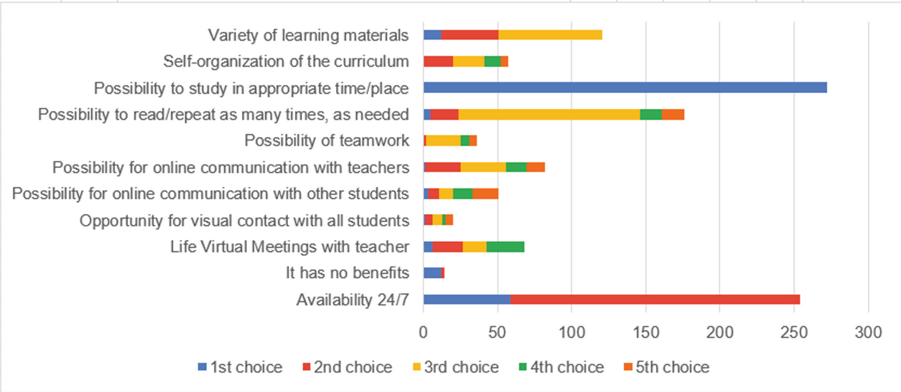


Fig. 2. The major benefits of online programming language classes, stated by students.

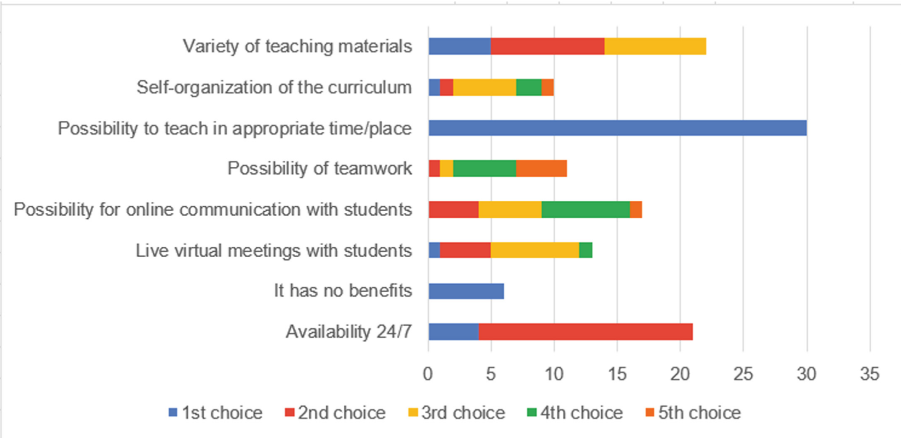


Fig. 3. The major benefits of online programming language classes, stated by teachers.

The major challenges as stated by both teachers and students were as follows: i) not enough feedback ii) the lack of social contact and iii) lack of technical equipment/skills (see Fig. 4 and Fig. 5). Specifically, students also listed the followings i) hard to solve problems on their own (47%), ii) too fast pace in the course (28%), and iv) too many tasks (15%), as the other principal challenges (see Fig. 4).

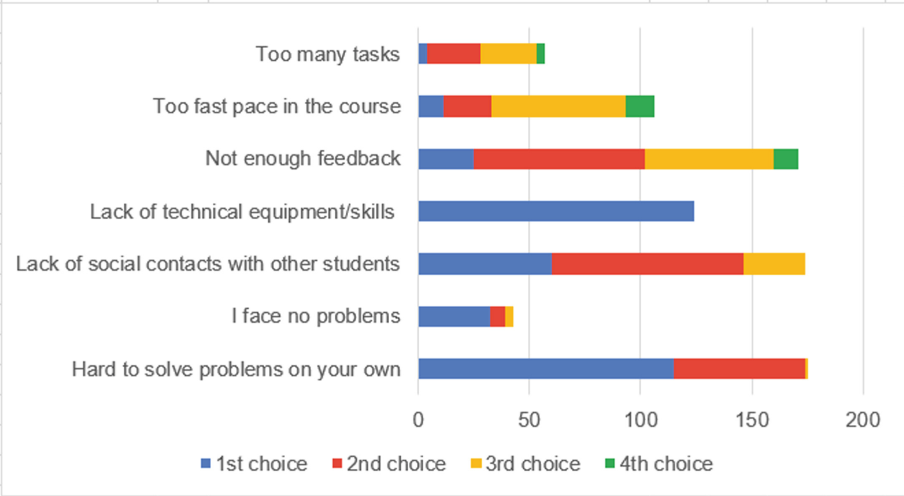


Fig. 4. The major challenges of online programming language classes, stated by students.

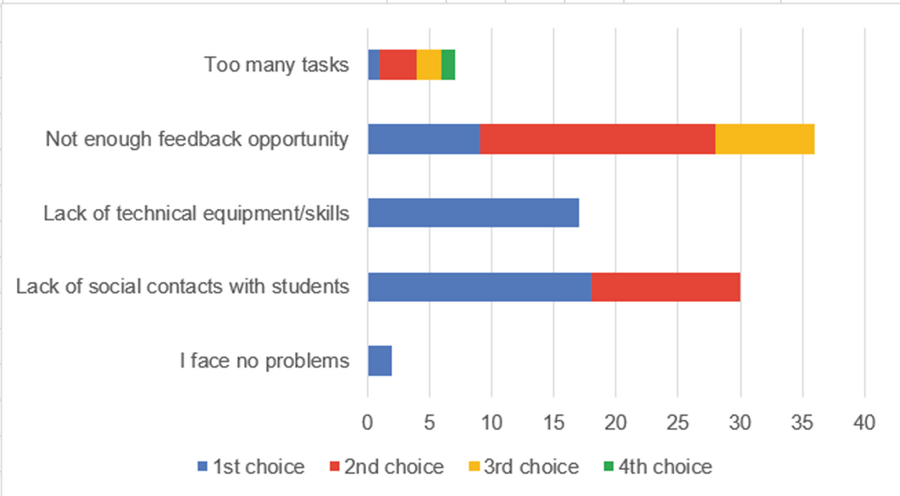


Fig. 5. The major challenges of online programming language classes, stated by teachers.

As the educational elements that support lessons, students preferred i) video tutorials (58%), ii) live classes (58%), iii) simulations (52%), iv) external video tutorials (49%), v) external lectures (41%), vi) games (25%), vii) animations (24%) and viii) e-quizzes (23%) (see Fig. 6).

On the part of teachers, they listed the educational elements that support lessons as follows; i) simulations (36%), ii) games (32%), iii) e-quizzes (32%), iv) external lectures (30%), v) real-life projects by mentoring sessions (30%), vi) programming tasks with automated feedback (28%), vii) animations (26%), viii) collaborative whiteboard applications (26%), ix) external video tutorials (26%), x) live classes (23%) and xi) video tutorials (23%) (see Fig. 7).

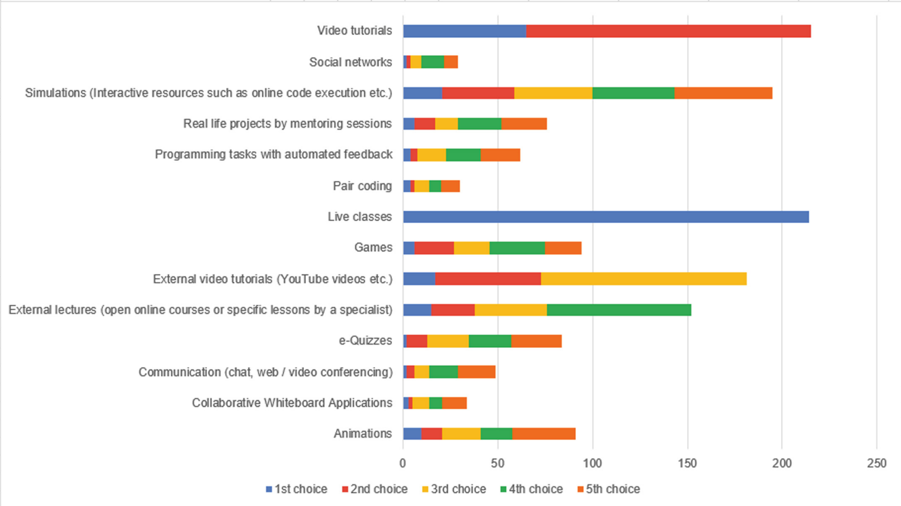


Fig. 6. Educational element(s) to be offered in online programming language classes, stated by students.

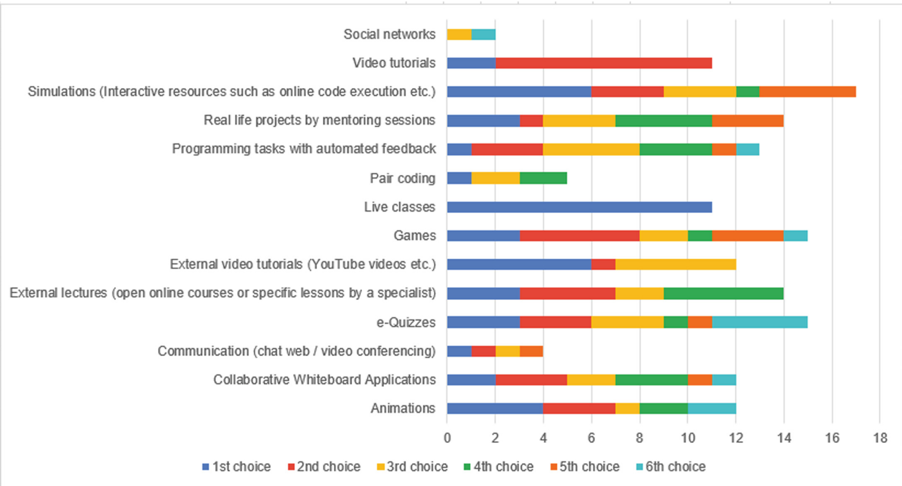


Fig. 7. Educational element(s) to offer in online programming language classes, stated by teachers.

Furthermore, teachers also stated that they would most like to employ project-based learning (49%), gamification (45%), simulation-based learning (34%), and flipped classroom (30%) activities in their classes as well as lecturing in the form of video conferencing (28%) (see Fig. 8).

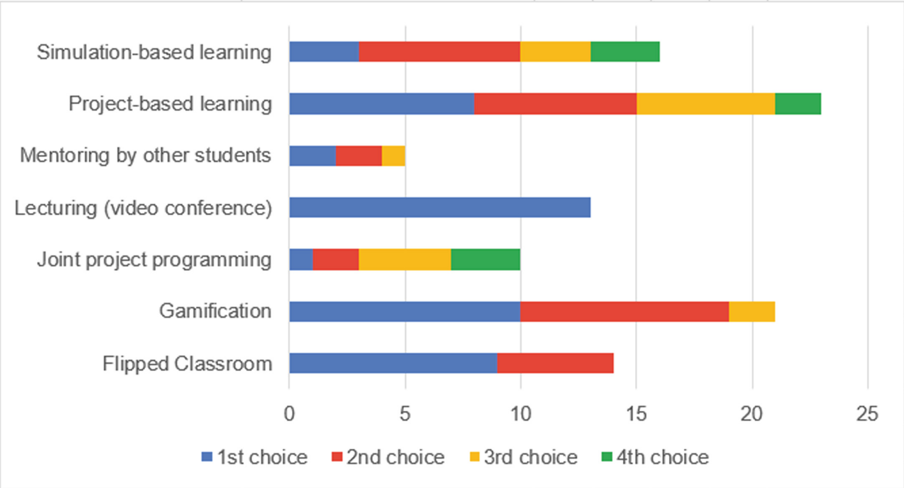
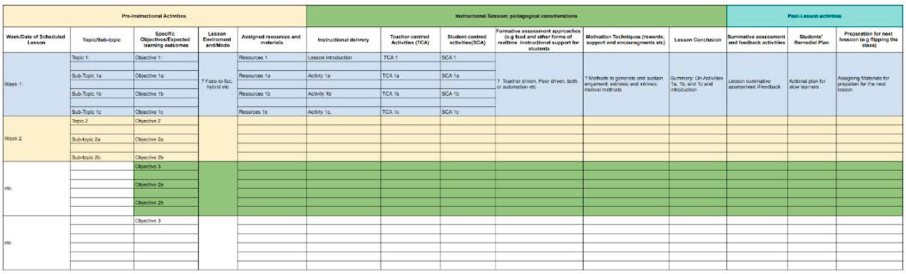


Fig. 8. The learning/teaching methods and techniques that teachers like to employ in their online programming language classes.

We also analysed the existing course plans from five European countries. According to the course plan analysis, we have identified the weekly topics, learning objectives, and related pedagogical approaches.

Based on the data from the questionnaires and the course plan analysis, we made a content analysis to determine the instructional objectives. Then, we sequenced the content, determined the instructional strategies, and designed the messages, by utilizing the content analysis. As a result of these steps, we developed a course plan template (see Fig. 9).



Pre-Instructional Activities					Instructional Session: pedagogical considerations						Post-Lesson activities		
Week/Date of Scheduled Lesson	Topic/Sub-topic	Specific Objectives/Expected learning outcomes	Lesson Environment and/Mode	Assigned resources and materials	Instructional delivery	Teacher-centred Activities (TCA)	Student-centred activities(SCA)	Formative assessment approaches (e.g fbed and other forms of realtime instructional support for students	Motivation Techniques (rewards, support and encouragments etc)	Lesson Conclusion	Summative assessment and feedback activities	Students' Remedial Plan	Preparation for next lessoon (e.g flipping the class)
Week 1:	Topic 1:	Objective 1:	? Face-to-fac, hybrid etc	Resources 1	Lesson introduction	TCA 1	SCA 1	? Teacher driven, Peer driven, both or automation etc	? Methods to generate and sustain engament, extrinsic and intrinsic motival methods	Summary: On Activities 1a, 1b, and 1c and introduction	Lesson summative assessment /Feedback	Actional plan for slow learners	Assigning Materials for prepation for the next lesson
	Sub-Topic 1a	Objective 1a		Resources 1a	Activity 1a	TCA 1a	SCA 1a						
	Sub-Topic 1b	Objective 1b		Resources 1b	Activity 1b	TCA 1b	SCA 1b						
	Sub-Topic 1c	Objective 1c		Resorces 1c	Activity 1c,	TCA 1c	SCA 1c						
Week 2	Topic 2	Objective 2											
	Sub-topic 2a	Objective 2a											
	Sub-topic 2b	Objective 2b											
etc		Objective 3											
		Objective 2a											
		Objective 2b											
etc		Objective 3											

Fig. 9. The course plan template.

The template has features, especially in terms of instructional strategy issues which are closely related to student-based learning approach such as feedback, gamification, and flipping the classroom. In this framework, conscious efforts are made to put the teacher (lecturer) at the centre of the teaching and learning process as a facilitator and active student learning. That this process of making students active learners revolves around the teachers' pedagogical competence. This framework clusters the dimensions of the pedagogical competence of the teacher into three main dimensions.

- Pre-Instructional Activities: Under this dimension, it is proposed that teachers embed themselves in the planning of the lesson with the student in mind. There these pedagogical requirements should be met, namely: Topic and/or subtopics, Specific objectives (expected learning outcomes), the environment for the learning (and mode) and resources/material (could be initial and later added on) for the lesson.
- Instructional Sessions: Even before the lesson delivery, the teacher is expected to align the pre-instructional projections to the instructional and post-instructional delivery sessions. Consequently, in planning for and delivering the lesson the framework proposed teacher thorough consideration of the following: i) The lesson delivery (introduction part), ii) teacher-centred activities (specific teacher roles), iii) Formative assessment (real-time feedback activities), iv) motivation techniques (reward and encouragements), and v) Lesson conclusion
- Post-Instructional Activities: As much as the previous session depicts the active component of the learning trajectory, the framework considers this post-instructional session essential for teachers to showcase empathy and promote individual learning support. Consequently, the framework proposes the following activities: i) Summative assessment (overall feedback inclusive), ii) Remedial plan for students (supporting slow learners) and iii) preparing students for the next lesson.

The following Table 1 gives a summary of all dimensions, pointing out the assessment questions.

Table 1. Lesson plan quality assurance and compliance guide.

Session	Sub-dimensions	Assessment question
Pre-Instructional Activities	Topic and/or subtopics	Is the topic aligned to the one formulated on the Course Plan or Outline/ National curriculum?
	Specific objectives/ Expected learning outcomes	Are the objectives/ learning outcomes well-defined and measurable?
	Learning environment and mode	Are the learning environment and the mode clearly defined? Does it facilitate students' active learning?
	Assigned resources/material for the lesson	Is there an initial overview or description or the resources and their functionalities or application in the lessons?

(*continued*)

Table 1. (*continued*)

Session	Sub-dimensions	Assessment question
Instructional Sessions	The lesson delivery	Is the lesson delivery scaffolded to promote students' learning progress? Are the sequences of lesson delivery aligned with the assigned materials? Is the lesson showcasing evidence of learner-centred, opportunities for interactive learning and active engagement?
	Teacher-Centred activities (specific teacher roles)	Are the teacher roles taking the centre stage in the lesson, or rather functioning as a facilitator/mentor?
	Student-centred activities (Specific student roles)	Is there evidence of learning structured to induce learner progression through motivation?
	Formative assessment (feedback)	Is there evidence of the learning structured to induce learner progression and through formative assessments - including feedback?
	Motivation techniques	Are the motivation techniques to sustain student learning defined/outlined?
	Lesson conclusion	Do the lessons have a summary serving as a guide for student reflection/recollection?
Post-Instructional Activities	Summative assessment	Is the structure for Summative learning assessment (Overall Feedback) defined/outlined?
	Remedial plan for students	Does the lesson outline the strategy to support late achievers/ remedial plans for slow learners?
	Preparing students for next lesson	Does the lesson connect what has been learnt to what is to be learnt and prepare learners for the next lesson? For example, using the Flipped classroom approach for the next lesson

Kemp Design Model provides the next steps as developing, implementing, and evaluating the course design. Accordingly, the course content, including educational materials will be developed. Then, the course design will be ready to implement and get feedback as the evaluation of it by students and teachers.

4 Discussion and Conclusion

As showcased research process, we developed a course plan template and a course design. The course design was developed for undergraduate programming languages in hybrid learning environments. The template has features, especially in terms of instructional strategy issues which are closely related to student-based learning approaches such as feedback, gamification, and flipping the classroom. Based on the insights throughout the design and development process of the course plan template, we presented implications in terms of hybrid learning environments and programming languages courses.

In this context, we investigated the learning styles and needs of both students and teachers by utilizing online questionnaires. The analysis of the answers to the questionnaires allowed us to elicit information on online education from Bachelor level Engineering students and from teachers. In particular, the major benefits, both from teachers and students, were the variety of learning materials -such as simulations, video tutorials, external resources, the self-organization of the curriculum, the possibility of teamwork. The teachers also claimed that their preferred integrative educational methods were gamification, flipped classroom, project-based learning. The major challenges for effective online environments were not enough feedback and the lack of social contact among students.

As shown in Table 1, the lesson planning was to be measured by teachers to ensure the facilitation of active and student-centred learning practices. Dicheva and Dichev [14] present an active learning model that claims both flipped learning and gamification can be leveraging strategies. To support the role of teachers as mentors, their approach is to ensure learner-centred, active learning and reinforce intrinsic motivation. Thus, they offer such a method where gamification is used to effectively complement and support the flipped model of learning. Rincon-Flores and Santos-Guevara [8] also mention the power of gamification as a reward-based system to promote active class participation and improved student performance, especially for the transition from face-to-face to virtual environments. Amissah [15], on the other hand, examined the advantages and challenges of online project-based learning and resulted that there are more advantages than challenges. Moreover, the challenges can be overcome in the case of well-structured and well-conducted process. The advantages, for example, promoting academic achievement and problem solving, revisiting feedback and making comments. Similarly, in our study, we also resulted in focusing on these teaching methods.

Yuhanna et al. [16] investigated the advantages and disadvantages of online learning and they highlighted, as one of the significant advantages, the media diversity that of including text, audio, graphics, animation, video, and downloadable software. They also mentioned the high amount of resources that are available online. Mukhtar et al. [17] explored the advantages and limitations of online learning and they listed self-directed learning as one of the advantages. Similarly, we also found that the variety of learning materials and flexible curriculum are among the major benefits. Dumford and Miller [18], in their study in which they investigated the advantages and disadvantages of online learning in terms of student engagement, stated that traditional face-to-face environments seem more likely to promote collaborative learning. In contrast, we found that the possibility of teamwork is among the major benefits of online learning environments. Indeed, by utilizing the power of certain teaching methods mentioned above, the possibility of teamwork can be encouraged.

Dumford and Miller [18] stated that both junior and senior students complained that they had fewer opportunities to communicate with teachers and other students. Similarly, in our study, we also revealed that one of the biggest challenges in online learning of programming courses for both students and teachers was the lack of social contact. Dumford and Miller [18] also stated that less exposure to effective teaching practices and lower quality of interactions were reported by the students. Besides, Hu et al. [1] revealed that the problem of having not enough interactions between teachers and students has continued during the Covid-19 period so teachers should be encouraged to guide students' learning by giving feedback or questioning during the class. Mukhtar et al. [17] also mentioned the lack of feedback as a limitation of online learning. Similarly, we also established the lack of enough feedback as one of the major challenges in online learning environments.

Based on these findings, we conclude that there is the need for a hybrid model in which online and face-to-face education is blended and enriched with different kinds of materials and various educational methods. Then, we focused on designing a course plan template by following the Kemp Instructional Design Model, using a student-based learning approach and adopting innovative educational strategies. The course design was developed for undergraduate programming languages in hybrid learning environments. The template has features, especially in terms of instructional strategy issues which are closely related to student-based learning approaches such as feedback, gamification, and flipping the classroom. Pedagogical abilities are required to deliver enough information, guidance, and structure to let students shape their knowledge and skills through online platforms. New hybrid courses require different strategies to present content, interact with students, and assess course outcomes. We hope our framework could represent a useful template, a core instructional design, for any course in a hybrid learning environment in Engineering, Science and Technology Education.

All in all, we, as the RECOM project team, presented a course design framework, which targets undergraduate programming languages in hybrid learning environments. The subsequent steps of the Kemp Model have not been completed yet. Therefore, the future works for us to deliver the course using this course template and evaluate it. In the next months, we will deliver the course using this course design and will evaluate it in order to investigate if the proposed online/hybrid teaching strategies (with gamification approach and online technologies integrated) are effective to improve students' learning, motivation and interest, to maintain students' concentration, and to enhance students' learning.

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Facing the Didactic Emergency During Covid-19 Pandemic in an Analytical Chemistry Laboratory

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Abstract. The active learning environment adopted in an undergraduate course of instrumental analysis was completely rethought and reshaped to accomplish the strict lockdown conditions during the most severe period of pandemic (from march 2020) when all the didactic activities (lessons and laboratory) were fully online and during the less severe condition of the following year, when a blended online learning approach allowed to attend in presence the lab activities but to frequent only online the class didactic activity. The instrumental analysis course has been since several years structured on a problem/project-based learning (PrPBL) cycle, consisting in a part of experimental project accomplished by the students, a subsequent laboratory activity, where the procedures defined by the students are applied to the specific problem to be solved, and a final restitution from each group to the whole class. The pandemic forced us to implement in the learning cycle both asynchronous and synchronous online strategy to keep the PrPBL approach and the active interaction between the students. The extensive use of simulated data and of breakthrough rooms (allowed in Teams® application) was found a highly effective way to reach satisfactory learning results, comparable with, and in some case better than, the ones obtain in conventional teaching mode. In this work we present how the online PrPBL approach was developed and applied to a lab experience concerning a conductimetric titration.

Keywords: Blended learning Active learning · Group investigation · Conductometry · Chemistry laboratory · Analytical chemistry

1 Introduction

1.1 The Theoretical Framework: Teaching

Problem Based Learning (PBL) is a teaching methodology widely applied and validated, through studies and experimentations, in different educational and disciplinary contexts. It is acknowledged that the first formal application of a PBL model was within the medical program at the McMaster University in 1969 [1]. Indeed, the original spirit of this didactic model should be ascribed, as many authors have pointed out [2, 3], to the

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"learning by doing" pedagogical approach proposed by John Dewey still at the beginning of the last century. Several models have been proposed to implement a PBL approach in an educational setting [4]. Nevertheless, besides the differences among such models, it is possible to point out some common steps (or points) that should always be present in a PBL approach:

- The problem is presented to students organized in groups
- Students must organize, within the groups, the investigation of the problem consulting the provided materials; search for new materials, identify their learning need and missing knowledges, and assign specific roles to the different components of the group.
- The group discusses to generate and evaluate hypotheses for the problem solution
- The group prepares an “action plan” to formulate/produce a solution
- The group self-evaluates the results obtained.

As it is possible to understand from the instructional steps described above, the theoretical framework of PBL has a clear constructivist fingerprint. In fact, the learning process is strongly centered to the learner and is intended as a process of continuous intellectual growth which starts from prior knowledge and, taking advantage from the active interaction with an engaging problematic situation, allows the construction of new knowledge based on a critical reflection about the experience done [5, 6]. Obviously, a PBL situation may be proposed also to single students, but if problems grow in complexity and extension became unavoidable to work in group and in such a situation it is easy to both mobilize many kinds of soft skills and activate metacognitive and reflective processes [7, 8]. In PBL instructional approach the role of the teacher is, from a side, to define adequate problems that lead students to investigate and face unknown or not fully acquired aspects of their knowledge and, from the other, to support the different groups by mediating the discussions and guiding them, avoiding being intrusive, toward solving the problem.

Project Based Learning (PrBL) was born in Denmark around the same time as the first experience at McMaster University. In a PrBL the object of the task assigned to groups of students is specific and well defined in advance. To complete the task, the group must organize its activities and gather all the necessary resources. For example, the final product can be a physical object, a presentation, or a poster. The main difference between the two learning approaches can probably be found in the fact that PBL usually presents an open and sometimes ill structured problem that provides a context for inquiry and learning while in PrBL the effort required to the student is that to accomplish a specific task by entrusting the learning process mainly to the context, complexity, and authenticity of the task itself [9].

1.2 The Theoretical Framework: Analytical Technique

Conductometry appears increasingly neglected in undergraduate textbooks. A rapid survey of the literature points out this fact. For example, both of two well-known textbooks of the eighties of the past century [10, 11] have a complete chapter dedicated to conductometry with an extended discussion of both theoretical and practical aspects, even if mainly acid-base titrations are fully described. In a more recent book [12] there are only eight pages discussing conductometry citing only acid base titration, while in [13] and [14] one can find only short notes on the argument. Quite surprisingly, in some of the most popular analytical chemistry textbooks [15–17] the technique is not even mentioned. On the contrary, in our opinion, conductometry is an inexpensive instrumental technique, unproblematic from a practical point of view and remarkably versatile in its applications.

Conductometry is used to perform the measurement of the electrical current transported by ionic substances, positively and negatively charged particles, through a solution. The parameter which is determined is the *specific conductivity* or *conductance* of the solution under analysis. In fact, one of the most frequent applications of such technique is the direct measurement of the conductance of a sample, which is a fair good estimate of the total concentration of salt (salinity) in a sample. This parameter is, for example, among the mandatory routine analytical controls for the Italian natural mineral waters [18] and it is among the composition data present in the label of bottled mineral waters. Conductance it also used to assess the performance of industrial and domestic desalinization systems. The higher the value of conductance is, the higher is the concentration of salt in the sample.

From the purpose of our didactic experimentation the most relevant feature of conductometry is the possibility to follow the variation of conductivity during a reaction. The most common example is acid-base titration where the change of conductance due to the progressive neutralization of an acidic species by means of the reaction with a basic one, for example the titration of chloridric acid (HCl) with sodium hydroxide (NaOH), may be easily followed. The shape of such titration is shown in Fig. 1.

Other than direct measurements and acid-base titrations, conductometry may be applied to a large range of applications, mainly complexation and precipitation titrations and in conditions sometime difficult to be afford with other techniques. It is also effective in some special applications [19, 20] which are the starting point of further problems proposed to the students but that are not considered in this paper.

In our didactic perspective, one of the most key features of conductometry to highlight is that with an easy enough calculation it is possible to predict the evolution of a chemical system and verify the goodness of fit or, at least, the closeness between the "model" and the "real world" with a quite easy and fast experiment. In Fig. 2 is shown the very good modeling of a conductometric acid-base titration. For simple systems, as the ones proposed to the students at the beginning of the course, all the calculations may be easily performed using a simple spreadsheet. Nevertheless, there are free applications that can be used in case of more complex system, but the description of these aspects is beyond the scope of this article.

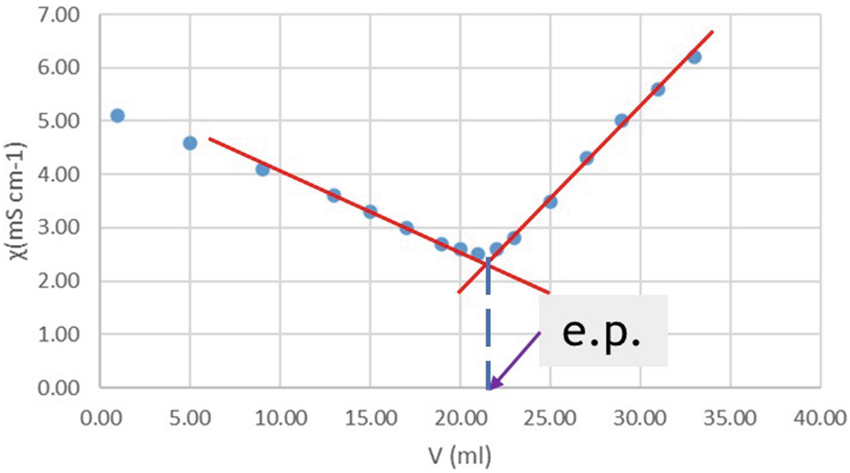

Fig. 1. Example of an acid-base titration of a strong acid (HCl) with a strong base (NaOH). The equivalent point (e.p.) is detected using the intersection of the two straight lines interpolating the linear portions of the two branches of the curve. The e.p. allows for the determination of the HCl concentration of the sample. The initial conductance of the acid solution is mainly due to H_3O^+. During neutralization due to OH^- addition, conductivity constantly decreases till the e.p., after which it starts to rise again due to the high conductance of OH^-.

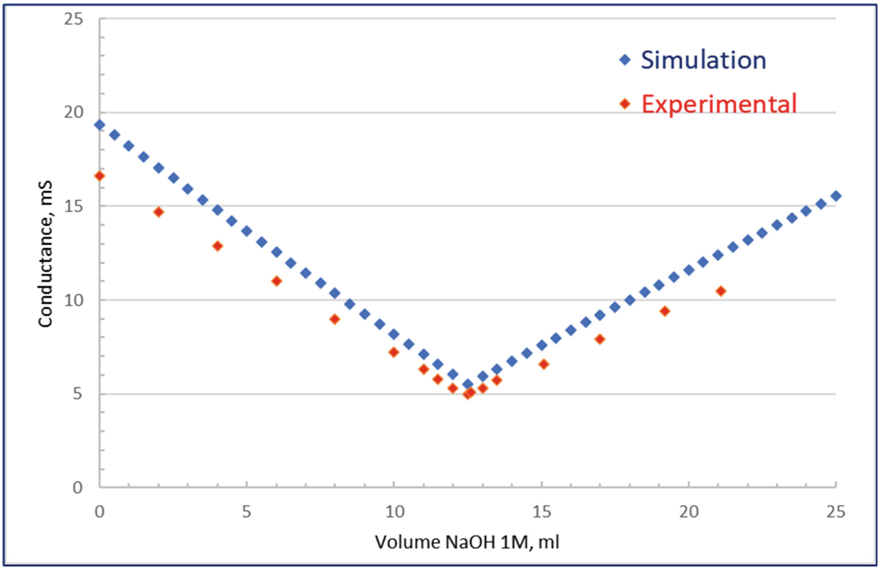

Fig. 2. Comparison between a simulated and an experimental plot of the conductometric titration of a strong acid (HCl) with a strong base (NaOH)

2 The Conductometry Experience Learning Cycle

2.1 Academic Years (Before Covid-19)

Considering the remarkable didactic features of conductometric titration, such analytical method has for years been an integral part of the laboratory experience offered in the teaching of Instrumental Analytical Chemistry at the final semester of the BSc Industrial Chemistry course at the University of Bologna. Almost all laboratory activities of the course have always been organized using a combination of both PBL and PrBL models that we can name Project and Problem Based Learning (PrPBL). In this approach an analytical problem is assigned to each working group. We attempt to form heterogeneous groups, using carrier information, previous attended high school, and gender. The *project* is usually the definition of a complete analytical procedure that should be able to solve the assigned *problem*. The first phase of the students' work is conducted by the different groups in the classroom, on the basis of material given by the teachers. The second phase is the practical realization of students' projects in the lab. The final phase consists in the revision of work done by the different groups and is conducted in the classroom. Figure 3 shows the scheme of the "before-Covid-19" learning phases related to the conductometric experience. The teachers provided the students with a very concise instruction sheet in which there is the statement of the problem:

- *It is required to set-up a procedure for the determination by conductometry of HCl (or NaOH) in a solution at a concentration in the range 0.1–0.01 mol* L^{-1}.

In addition, the students are informed to consider the following focal points:

- *Concentrations of the test solutions to be titrated*
- *Type and concentration of the titrant solutions*
- *Division of tasks*
- *Number of replicas*

However, this learning cycle was based, albeit asynchronously, on the online Moodle platform that was used in almost all the phases of work. In the first phase the platform served both as a deposit of the consultation material and for the submission of the drafts of the procedure by the groups. In the last phase it is used for the delivery of the final report. On the platform the teacher can examine the drafts, limiting his inter-ference in the rare cases where some obvious logical inconsistencies in the products are observed. The identification of weaknesses, or real errors, is entrusted to the student's autonomous discovery during the lab activity of the second phase of the cycle. This choice extends the execution times which are limited by the availability of laboratory spaces and therefore sometimes requires a return to the laboratory outside the conventional hours. But we believe that this aspect is one of the strengths of the whole didactic proposal, and we have never abandoned it.

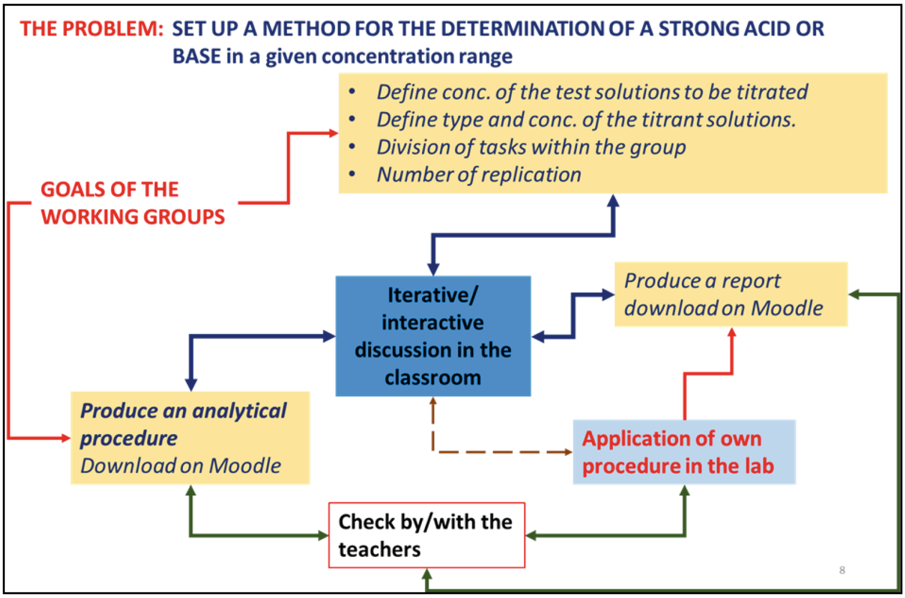

Fig. 3. Flowsheet of the PrPBL cycle adopted in pre-pandemic (BC years) laboratory activities

As it is possible to see from the flow sheet of Fig. 3, there are two main poles in the learning process. The first is in the lab, where all the project effort of the students is put in action, and the second one is in the classroom, with the group discussions conducted before and after the lab activity. The classroom is the place where reflection and metacognition about the nature of the problem and of the strategies adopted for its resolution are stimulated.

2.2 Academic Year in Full Lockdown (2019–2020)

All over the world, the pandemic emergency pushed all the education institutions to quickly convert the conventional way of teaching, mostly consisting of lecturing in the classroom and performing guided experiments in the lab, into a completely different types of didactic. A quite relevant number of reports about the ways adopted to overcome the emergency has been published in the past couple of years. It is already possible to mention some extensive reviews covering the issue from different point of views. In particular, Bond et al. [21] made an investigation, extended to all the disciplines, concerning the strategies adopted to modify course curricula during the first semester of pandemic. The authors selected 282 studies; most of such studies used synchronous collaboration tools but only 31 of them were centered on course redesign to address the new didactic situation. The review of Kelley [22] is focused to summarized and evaluate the impact on learning of the modifications made to chemistry laboratory activities during pandemic. The author cites 91 papers, more than half of them published in a special issue of Journal of Chemical Education [23]. The more common adjustments reported involved: distributing data collected in previous years, distributing procedures or videos from which collect data, furnishing instructions to perform experiments at home, and using digital simulations or virtual environments.

At the University of Bologna, the pandemic emergency of 2020 has determined the total lockdown of all teaching activities starting from 5 March, at the very beginning of the semester in which our course is held. The rapidity of the didactic change and the difficulties, both for teachers and students, in becoming familiar with the new learning relationship determined by distance teaching were the main problems encountered and, probably, not completely overcome. In our university, Microsoft's Teams® platform was chosen for distance learning and, of course, very few people were familiar with the software and its potential.

However, the emergency prompted us to review and reformulate the educational approach described in the previous paragraph, trying to exploit conductometry as a tool for a better understanding of the nature of electrolytic solutions and to predict and interpret the trends of the titration curves, even of a certain complexity. In this transition year the learning cycle was abruptly reduced (see Fig. 4) and, given the impossibility of the students to check their own procedure in the lab, the planning part of the cycle was removed. Furthermore, due to the short time available to apprehend the use of group working within the functionalities of the communication software (breakout rooms, for example) also the interactive discussion within the groups and in the virtual classroom was strongly reduce or, at best, limited.

The solution we found was to imagine a situation where the group was in charge of analyzing a set of experimental raw data left, without further explanation, by a colleague who went on vacation. This learning situation forced us to produce a lot of simulated data (actually, for each of the techniques taught in the course), in order to provide different data to the groups. This approach allowed us to have the students work on "real" data, to involve them in the design of the analytical procedure that the colleague should have used, and to make them able to produce a final report. Figure 5 shows an example of raw data and of the information given to a group. The curve had to be plotted and interpreted by the students; in the case reported raw data must be corrected for the dilution occurring during the titration.

The course arrived safe and sound to the end, but we realized, examining the material produced by the students that, as we had to imagine, the degree of understanding of the phenomena was much lower than that achieved the previous year and the description and elaboration of data were, very often, schematic and repetitive. More than this, the experience of the full lockdown allowed us to clearly highlight three points that must remain fixed in our learning cycle: i) the project of the experiments defined by the students; ii) the supervision of interaction within the group; iii) the promotion of interaction among the groups. In addition, we verified that simulating an experimental conductometric curve were not so difficult to do and that this task could also have been carried out by the students, if they were adequately scaffolded.

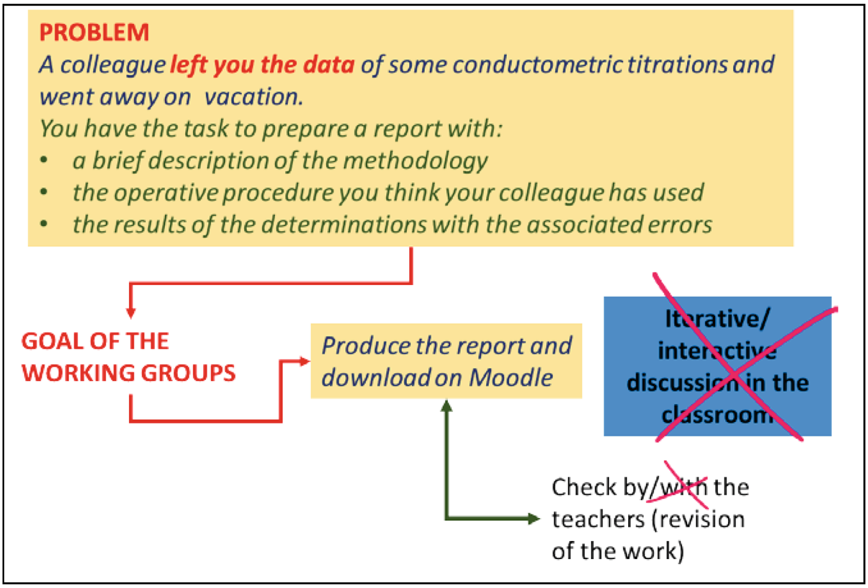

Fig. 4. The reduction of the learning cycle of the conductometric titration "experience" during the complete lockdown of university didactic activities.

DATA	Groups		
B1, MA1	G01L	G01M	G10M
B2, MA2	G02L	G02M	G08L
B3, MA2	G03L	G03M	G08M
B4, MA1	G04L	G04M	G09M
A1, MB1	G05L	G05M	G09L
A2, MB1	G06L	G06M	
A3, MB2	G07L	G07M	

Vadd (mL)	Cond (mS)	Vadd (mL)	Cond (mS)
0	0.88	26	7.28
2	1.69	28	8.73
4	2.38	30	10.13
6	2.99	32	11.43
8	3.53	34	12.66
10	4.00	36	13.8
12	4.43	38	14.87
14	4.81	40	15.88
16	5.15	42	16.83
18	5.47	44	17.72
20	5.76	46	18.56
22	6.04	48	19.36
24	6.36	50	20.11

DATA B1
Analyte: Sodium acetate.
Analyte Concentration: unknown.
Titrand: HCl. Concentration: 0.1000M
Sample volume: 25.0 mL

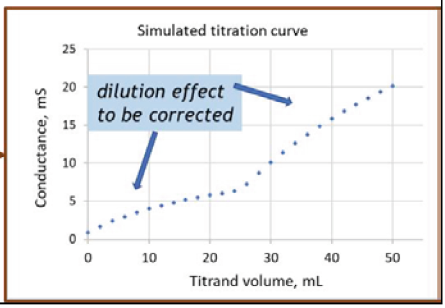

Fig. 5. An example of the raw data set B1, given to the groups G01L, G01M; G10M. The data plot shows a strong dilution effect. The students know nothing of the procedure adopted by the colleague except the titrant used and its concentration

2.3 Academic Year 2020–2021 (After Covid-19)

In the second semester of academic year 2020–2021 the limitation imposed in the previous full lockdown were loosened. In the blended mode learning it was allowed to frequent the laboratory, even if in a limited number of people: no more than twenty students at a time (what we called Macro Group (MG) composed by 4–5 independent working groups) while the total number of students was around eighty. On the contrary, all lessons were held online. This time we were a little more able to take advantage of the opportunities offered by the online platform, hence we attempt to implement our original PrPBL cycle, with some modifications, in the new online format.

Groups organization was quite complicated because we decided that a number of groups higher than ten could have reduced our ability to have a reasonable control of the activity, mainly in the project part of the experience. Hence, the project and discussion part were held in a virtual class with a total of around 40 students at a time corresponding to 9–10 working groups; in each group there was also one student who would have followed remotely also the lab work. Figure 6 shows the scheme of the lesson planning for the conductometric experience.

	LESSON	PROJECT ACTIVITY	LAB ACTIVITY	HOME ACTIVITY
week 1	Conductometry theoretical basis MG: A, B, C, D			
week 2		(MG_A e MG_B) strong acid, MIX of two bases		
week 3		(MG_C e MG_D) strong base, MIX of two acids	Work in lab (MG_A)	
week 4		(MG_C e MG_D) New problem…	Work in lab (MG_B)	Elaboration / reporting (MG_A)
week 5			Work in lab (MG_C)	Elaboration / reporting (MG_B)
week 6			Work in lab (MG_D)	Elaboration / reporting (MG_C) …

Fig. 6. Plan of the activity for the conductometric experience during blended mode teaching. In week 4, a new problem is presented to two MG. A complete experience was completed in three weeks

To each group a private channel within the main Team of the class was assigned. The channel was the place where each member of the group was able to interact with the others and discuss the proposed problem. Draft documents where shared online and directly written on the platform, while the teacher was able to verify the advancement of group's work visiting the channel or intervening when requested without disturbing the other groups.

As shown in Fig. 6, the outline of the didactic intervention scheme involved a first exposition by the teacher of the basic principles of conductometry, focusing on the aspects related to the relationship between ionic mobility, equivalent conductivity at infinite dilution and measured conductance. In the planning phase, to the two MG in plenary session two problems were presented, the first quite binding:

1. *A method must be developed to determine hydrochloric acid (for MG A) or sodium hydroxide (for MG B) in an unknown solution in which it can be present at a concentration ranging between 0.1 and 0.01 mol·L*$^{-1}$

   and the second quite open.

2. *You must develop a method to determine the quantitative composition of a mixture of a strong and a weak base*

For this second task, groups were free to choose the mixture to analyze. Finally, this additional goal was assigned:

– *Make and estimate of the conductivity during the titration and at the ending points and evaluate the goodness of the prediction based on the experimental work.*

In Fig. 7 the learning cycle of the conductometric experience in blended mode is described. It was possible to extend the requests to the students, adding to the procedure project also the autonomous definition of a test titration of a mixture of couple of acids or bases, one weak and the other strong. The other important extension was the request to present in the draft of the procedure also the simulation of the titration curve of the

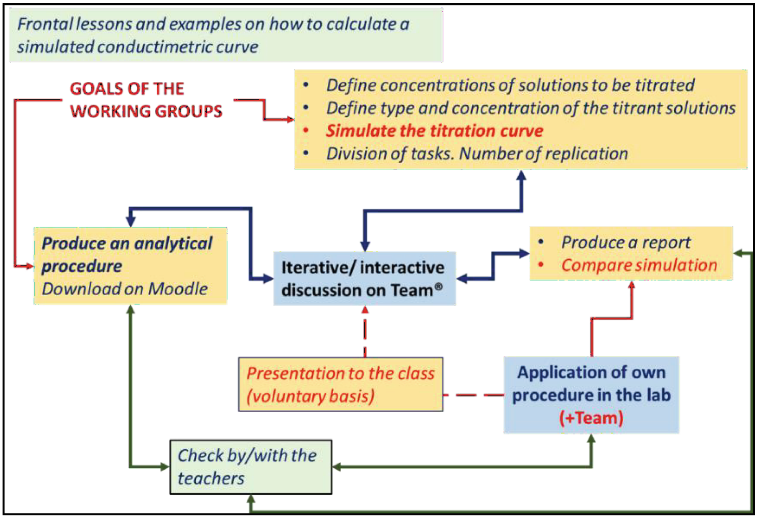

Fig. 7. Learning cycle of the conductometric experience in blended mode. Laboratory activities were performed in the lab while project and discussion in virtual class and breakout rooms. Red italic are the new activities introduce in the learning sequence

first task (titration of a strong acid or base). This was very useful also for the possibility to check experimentally the simulation made, and, maybe, to revise the calculation or redo the experiment. During the preliminary project session, many checks of the group elaboration were made in plenary, allowing for a strong interaction among the groups and a reinforcing of the adequacy of provisional conclusions. Differently from the usual way we were able to extend the discussion also on the results of the experiments and on the reasons for having obtained good or bad results. Each group had to appoint a rapporteur who must be different each time the group had to present its state of advancement in the plenary session. Check, feedback, and revision to the written products were made using the Moodle platform.

3 Results and Conclusions

The reports presented by the groups in the blended conductometric experience got an average score (we used an evaluation grid) of 70/100. Three groups out of 14 got an insufficient score (<50). More than half of the groups were able to elaborate, using a spreadsheet, a theoretical prediction of their titration and to compare it with their own experimental results. The elaborations were reported in the final reports or in the attached spreadsheet. This goal was achieved not only for the relative facility to treat conductivity data and to produce reliable plot with easy calculation but also, in our opinion, for the effective collaborative work within the group and the possibility to clarify immediately with the teacher every doubt arising during the group discussion.

Despite the difficulties of distance teaching, a positive aspect to report is that such a modality has helped the students with some impairs in relating in public, to speak in the plenary sessions. At the end of the course all the students had at least once exposed the results of the group to the whole class. Such thing has never happened before in traditional teaching mode.

Comparing the scores in the final exams for the academic years from 2018–2019 through 2020–2021 we did not observe significative differences in students' performance: the mean grade along the three academic years is 26 ± 2 over a maximum of 30 and the percentage of sustained exams within the first examination session is always over 80%.

We did not perform a systematic analysis of student perceptions of the distance teaching mode but in informal discussions some students observed that both the project and the numerical exercise part of the activity was more effective in online mode, non-only for logistic reasons, such as inadequate classrooms and noise, but also because the online modality was found less distracting and more effective for exchanging information and immediate sharing of the documents to be read or written. These latter points should be considered, also in a non-pandemic situation, to improve the effectiveness of projector problem-based learning cycles.

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Experience-Based Training in Computer Science Education via Online Multiplayer Games on Computational Thinking

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Abstract. During the pandemics, the need to switch to the online setting gave us the opportunity to involve a group of university students in the design and realization of an online coding challenge among middle school classes: the first edition of the Italian Coding League (ICL). The second edition of the ICL competition took place in March 2022 and involved 609 students from 29 classes from 9 Italian regions. In the paper we present the format adopted for the organization of the ICL competition (an online game realized on a multiplayer game platform - one class, one player) and then focus on the experiential learning process adopted for university students involved in the initiative. An assessment of the entire activity is also presented, using data collected during the competition: we decided to refer to a public and scientifically recognized framework to define the challenges to be included in the competition and this allowed us to have explicit metrics useful to identify the degree of skills and competences exercised by the players during the competition.

Keywords: Experience-based Learning · Online Educational Games · Computer Science Education · Empowering Soft Skills · Near-mentorship Practices Innovative

1 Introduction

Experiential learning is quite common in Computer Science degrees in the form of capstone projects [1, 2] related to programming or data science. In this paper, we present an activity proposed as part of an introductory bachelor course on Computer Science Education, named ICDD (Computer Science for Creativity, Teaching, and Dissemination). The learning outcomes of the course include skills to design and conduct hands-on lab activities for introducing beginners to coding and programming. These hands-on activities are targeted to primary and middle school students and their contents are based on the national directions for teaching Computer Science in schools, proposed by the Italian Inter-university Consortium for Computer Science (CINI) [3, 4]. In pre-pandemic times,

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our students acquired such skills through design and conduction of in-presence laboratories mainly based on visual languages, such as Scratch [5] and Pocket Code [6]. The need to switch to the online setting gave us the opportunity to introduce an additional gamification element [7, 8], by involving our students in the design and realization of an online coding challenge among middle school classes, named Italian Coding League (ICL). ICL, jointly organized by the Digital School Interest Group of the University of Genova and by Edutainment Formula, took place in March 2022 and involved 609 students from 29 classes of 9 Italian regions. (The first edition of the ICL [9] was organized in 2021 with limited student involvement.) The competition was supported by the Smart O.C.A. (Smart Online Challenge Activity) online game platform [10] and was managed by the authors assisted by 15 tutors for a total of 112 h of training and competitions among the classes. The involvement of the ICDD students in the experience of the ICL organization pertained several different aspects including design of the format, selection of the set of questions proposed during the competition, and the online conduction of the activity during the different phases of the event.

Plan of the Paper. In Sect. 2, we present the format adopted for the organization of the ICL competition. In Sect. 3, we describe the experiential learning process adopted for the university students involved in the initiative. In Sect. 4, we present a summary of the outcome of the entire activity using data collected during the 2022 edition. In Sect. 5, we focus on considerations on the reflection phase for university students. Finally, in Sect.6 we address current and future work directions.

2 An Overview of the Italian Coding League 2022 (ICL 22)

The second edition of the Italian Coding League was proposed to Italian Schools by the University of Genoa. In line with the European Commission's Digital Education Action Plan 2021–2027, with stress on the need for basic education in computer science for all School levels, the Italian Coding League proposed to teachers and students a competition built on top of the Proposal for National directions for Teaching Computer Science issued by the CINI Computer Science and School Laboratory. In the organization of the event, special attention has been paid to the following topics: algorithms, programming, data, and information. The teaching model designed for the competition was made explicit to teachers and related to the syllabus of the Pedagogical Certification on the Use of Digital Technologies run by the University of Genoa in the context of the EPICT (European Pedagogical ICT Licence) Certification [11]. Gamification has a central role in the Italian Coding League format implemented via a multiplayer responsive game platform called Smart O.C.A. [10]. Game instances created in Smart O.C.A. can be played on students' devices and on interactive boards. Each player (individual or team) is represented in the game board by a virtual marker. The player rolls a virtual dice to proceed to the next cell. Each cell presents a quiz possibly accompanied by multimedia elements (videos and pictures). The 2022 edition took place in March 2022, with the first phase (selection) spanning from 8th to 25th. It involved 609 students from 29 classes from 9 Italian regions. The activity was managed by the organizers assisted by 15 tutors for a total of 112 h of training and competitions with the classes. Students, logged in from their classrooms, took on the challenge, consisting of a series of questions on computational thinking and coding, with the support of a university tutor. As mentioned at the beginning of the section, the questions were designed according to the Proposal for National Directions for Teaching Computer Science in School. Each class received feedback on its performance during the competition, to highlight the areas on which students obtained the best and worst results. In the first phase of the competition, each class participated in a challenge consisting of 15 questions. The resulting ranking was based on the number of correct answers, the time required to complete the challenge, and the interest and enthusiasm shown during the activity. To complete the activity, in the following days, the same questions have been proposed to the students of all classes involved in the first phase as an individual challenge (to compare team and individual performance). The average score obtained by all classes in the first phase was then used as a threshold for the admission to the final. The final took place on March 30^{th} and involved 13 classes. The finalists had to tackle a challenge consisting of 17 new questions. The winner received a ticket to the 2022 edition of the Festival of Science of Genoa.

The Smart O.C.A. platform engaged students in a competition based on gamification capable of motivating and focusing students' attention on the learning task. Students participate in the game first as a single team and then as individual players. Repeating the game in the two different modalities was used to derive a proficiency measure for classes and individuals. Thanks to the skills of teachers, groups of experts were created in the classrooms: those at the blackboard solving problems under the directions of their classmates; those from their tablets looking for information to share; and those in groups solving problems and sharing them in the class. A large "cognitive workshop" was activated in all classes with great internal cohesion and the stimulus of competition with other classes.

3 Behind the Scenes of ICL 2022

The ICL initiative turned out to be a successful experiential learning activity for the university students attending the third-year elective course "Computer Science for Creativity, Teaching and Dissemination" of the Bachelor of Computer Science at the University of Genoa of the academic year 2021–22 (second semester). The learning outcomes of the course include: "design and conduct hands-on lab activities for introducing beginners to computational thinking and coding". In this section, we take the point of view of the course and discuss the activities behind the preparation and conduction of the ICL event.

Question Preparation. The first activity in which university students were involved consisted in the preparation of the questions to be used in the challenge. After introducing computational thinking concepts, visual coding languages (Scratch), and to the CINI syllabus, the university students were required to prepare a set of questions/tests on Algorithms, Programming and Data that could be consistent with the level and goals of grade III in Secondary School. A further requirement was to formulate the questions according to the Computational Thinking guidelines, that is, to take inspiration from everyday algorithms (e.g., recipes, regulations, instructions), to distinguish algorithms from ambiguous or incomplete or non-terminating procedures, to focus on basic computational concepts such as variables, iteration, if-then-else, etc. Questions related to coding were based on programs written in visual languages like Scratch. Starting from the analysis of the questions of the first ICL edition, an engaging collaborative work involving students and instructors produced 32 questions for the two games (15 questions for the selection and 17 questions for the final). Collaborative tools such as Google Spreadsheet were used to organize the set of questions in accord with the different learning objectives of the CINI syllabus. The most voted questions were discussed in face-to-face meetings, in which students and instructors deeply analyze them according to different criteria (clarity, conciseness, appropriateness for the age target, diversity, etc.). Students were asked to review the proposed questions w.r.t. clarity and possible misinterpretations and ambiguities. Several rounds involving reformulations of each single quiz were needed to get to the final version. For the second game, a further difficulty was the requirement to link each question to one of the seventeen Go Goals of the Agenda 2030 (a further dimension in the collaborative sheet used during the game preparation). The collaborative work out of which the final questions emerged spanned three weeks and a total of 16 h of face-to-face meetings.

The questions used in the two games are publicly available in the Genial.ly web portal in the Italian language (final[1], selections[2]). Some examples from the final, are described below.

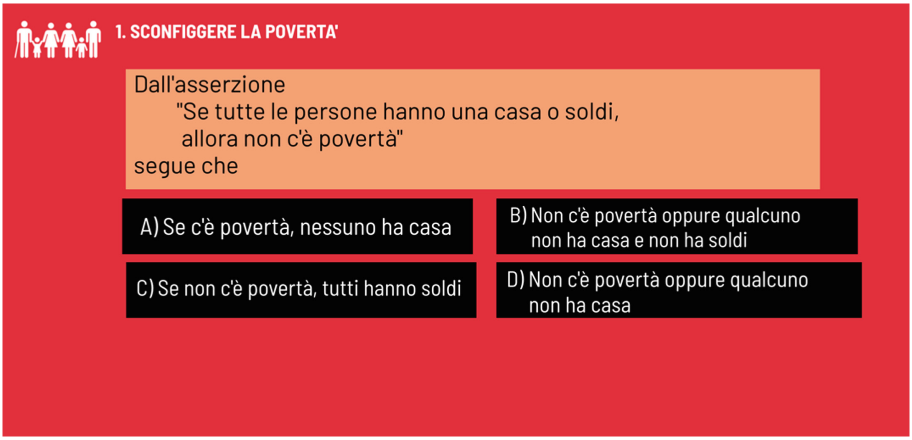

Fig. 1. Question 1: Defeating Poverty

Question 1 ("Defeating Poverty", the first Go Goal of the Agenda 2030), shown in Fig. 1, was about understanding natural language and basic concepts of logic: From the assertion "If all people have a home or money then there is no poverty" it follows that: (A) if there is poverty no one has a home; (B) if there is no poverty everyone has some

[1] Questions used in the ICL Final (inspired to the Agenda 2030) are available at: https://view.genial.ly/6239b3802c94460011229ebc/interactive-content-coding-agenda-2030

[2] Questions used in the ICL Selections are available at: https://view.genial.ly/624b3a8ac6a0b100110952e4/presentation-basic-presentation

money; (C) there is no poverty or someone is homeless and has no money; (D) there is no poverty or someone has no home.

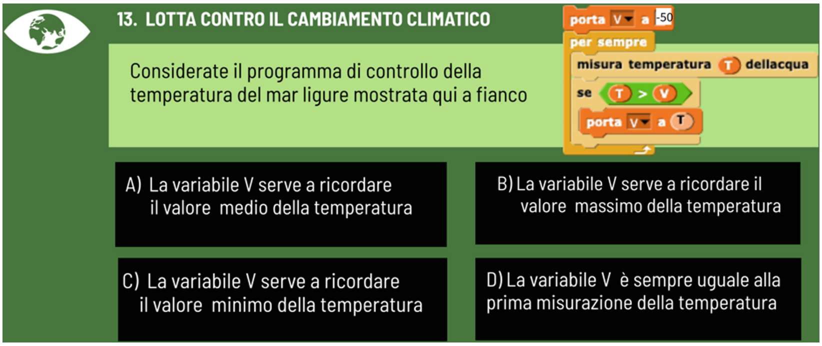

Fig. 2. Question 13: Climate Action

Figure 2 shows Question 13 ("Climate Action") that required the comprehension of a program written using block instructions. A variable V is used to maintain the maximum value in a loop used to monitor the current temperature T (e.g., coming from a sensor) of the sea. The possible answers were: Variable V is: (A) used to maintain the average value of the temperature; (B) used to maintain the maximum value of the temperature; (C) used to maintain the minimum value of the temperature; (D) always equal to the first measurement.

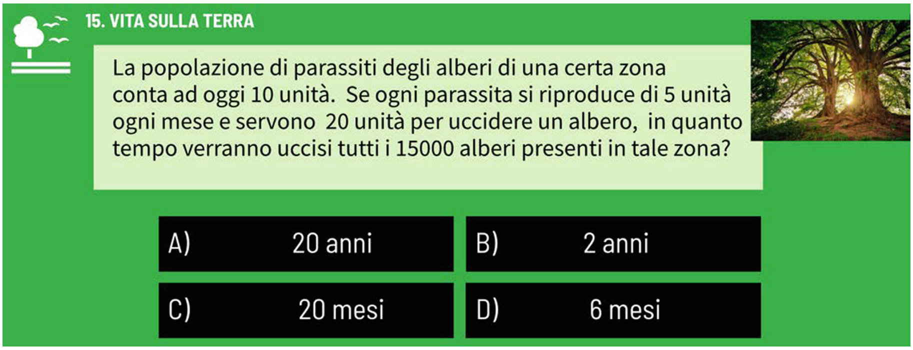

Fig. 3. Question 15: Life on Earth

Question 15 ("Life on Earth") shown in Fig. 3 required to calculate the effect, in this case with an exponential trend, of parasite reproduction after a certain number of months: The parasite population of trees in a certain area counts 10 units. If every parasite reproduces 5 times every month and 20 units can kill one tree, how much time is needed to kill 15000 trees? (A) 20 years; (B) 2 years; (C) 20 months; (D) 6 months.

Fig. 4. Question 17: Partnership for the Goals

Finally, Fig. 4 shows Question 17 ("Partnership for the Goals") dealing with an example of network analysis and the concept of centrality of a node in a graph: The graph with nodes 1–6 represents existing collaborations among international organizations: 1 is linked to 5, etc., which organization has the smaller distance from all other ones? (A) 2 or 5; (B) 1; (C) 2; (D) 4 or 5.

The considered questions have been associated with the objectives identified by the CINI syllabus: in the selection phase, the domains Algorithms, Programming, Data, and Information were considered; in the final phase, a question related to the domain Digital Awareness was added. Table 1 shows the classification of the questions according to the CINI syllabus in the corresponding topics.

Game Board and Graphical Design. As a second step, university students worked on the presentation of the challenge, creating a game board and a graphical layout for the different questions via the Genially editor. As shown in the quiz examples, the graphical layout for the seventeen questions used in the final was inspired to the seventeen Go Goals of the Agenda 2030. The questions were then linked to the Smart O.C.A. game instance to provide a multiplayer game experience.

Game Conduction. After several internal tests, our students brought their game instance to the field by conducting 609 participants during both the selection phase and the final match. The tutors guided the different classes with parallel sessions run via Google Meet. Responses from individual students in a class (or small groups) were aggregated using Wooclap, an online survey web app. The answer most voted by the class was then entered by the tutor in the Smart O. C. A. game board to continue in the game.

Table 1. Scope and Objectives of the CINI Syllabus. The third column reports the questions for each objective (in the Selection and the Final)

Algorithms	O-M-A-1. Detect possible ambiguities in the description of an algorithm in natural language	S9 F10 F15
	O-M-A-2. Express algorithms according to the ability of the performer and reflect on their correctness	S1
	O-M-A-3. Write algorithms, including using conventional notations, for simple processes from nature or everyday life or studied in other disciplines	S5
		S2 F11 F14
	O-M-A-4. Detect and express the conditions under which these processes end	S7 F2
Programming	O-M-P-1. Experiment with small changes in a program to understand its behavior, identify any flaws, modify it	S8
		S13
	O-M-P-2. Write programs that use nesting loops and selections	S2
		S14
	O-M-P-3. Use modular mechanisms, such as functions and procedures, in a simple way	S6
	O-M-P-4. Write programs using variables of simple types	S10
	O-M-P-5. Follow the evolution of processing also using variables that represent the state of the program	S4 F5
	O-M-P-6. Use variables in the conditions of loops and selections	S11 F8 F13
	O-M-P-7. Restructure programs to improve their comprehensibility	S15
Data	O-M-D-1. Recognize whether two alternative simple representations of the same information are interchangeable for one's purposes	F1 F9
	O-M-D-2. Perform simple operations on symbols representing structured information (e.g., binary numbers, "bitmap" images)	S3 F4
	O-M-D-3. Use variables to represent processing status	F3 F6
	O-M-D-4. Use structured variables to represent aggregates of homogeneous data (e.g., vectors, lists,…)	F16 F17

Table 2. Responses to the first phase questions referenced to the CINI syllabus

Area	topic	#questions	#answers	#correct	%correct
Algorithms		5	145	75	51,72%

(*continued*)

Table 2. (*continued*)

Area	topic	#questions	#answers	#correct	%correct
	O-M-A-1	1	29	5	17,24%
	O-M-A-2	1	29	20	68,97%
	O-M-A-3	2	58	26	44,83%
	O-M-A-4	1	29	24	82,76%
Programming		9	261	175	67,05%
	O-M-P-1	2	58	43	74,14%
	O-M-P-2	2	58	43	74,14%
	O-M-P-3	1	29	19	65,52%
	O-M-P-4	1	29	5	17,24%
	O-M-P-5	1	29	24	82,76%
	O-M-P-6	1	29	21	72,41%
	O-M-P-7	1	29	20	68,97%
Data	O-M-D-2	1	29	16	55,17%

4 Assessment Using Data Collected During the Competition

As the questions of the challenge were based on CINI framework we managed to obtain a global picture of the skills and competences performed by all the participants and at class level. The analysis of the 435 responses to the 15 selection questions sent by the 29 classes the statistics obtained are shown in Table 2. The questions related to algorithms, e.g., everyday algorithms, properties of algorithms, distinguishing algorithms from ambiguous or incomplete or non-terminating procedures, etc., were found to be the most difficult to tackle. Many of the programming questions were related to examples of scripts in Scratch, a language already used by all the classes, and thus were most familiar. As for the final, the 17 questions (thus with 221 total responses accepted) mainly covered the areas on algorithms and programming and one question on digital skills as described in Table 3.

Table 3 reports the statistics emerging from the analysis of the responses given in the final. Since the selection of classes to be admitted to the final was based on the average score obtained in the selection match, we expected an increase in the success rate. This improvement was indeed observed: the rate improved significantly in all categories: Algorithms (from 51% to 71%), Programming (from 67% to 78%), and Data (from 55% to 73%) categories. In the final as well, questions on algorithms represented the greatest difficulty.

Table 3. Responses to final phase questions referenced to the CINI syllabus

Area	topic	#questions	#answers	#correct	%
Algorithms		7	104	74	71%
	O-M-A-1	3	39	34	87%
	O-M-A-2	1	13	13	100%
	O-M-A-3	3	39	22	56%
	O-M-A-4	1	13	5	38%
Programming			78	61	78%
	O-M-P-1	1	13	6	46%
	O-M-P-2	1	13	13	100%
	O-M-P-3	1	13	12	92%
	O-M-P-5	2	26	18	69%
	O-M-P-6	1	13	12	92%
Data		2	26	19	73%
	O-M-D-1	1	13	13	100%
	O-M-D-3	1	13	6	46%
Dig. Comp	O-M-N-2	1	13	11	85%

Table 4 illustrates the comparison of the data collected during individual challenges, in which students individually attempted to answer the questions, with those collected from Wooclap during the selection phase (each class as a single player). Each record used in the student-level data identifies a student (or a pair/small group of students per tablet) rather than the entire class. Table 4 shows the response success rate for each skill area in the selection phase (with class- and student-level data) and the individual phase (with student-level data). In the individual challenge, the percentage of correct answers improved significantly for both the data and algorithm domains. In contrast, there seems to be no learning effect on programming. This could be attributed to the lack of data from some classes on the selection phase. In fact, not all classes participated in the individual challenge. Finally, a comparison between the class-level and Wooclap-level selection phase shows greater variability in responses for the data topic, which increases again in the individual phase.

Table 4. Correct response rate by topic area for the selection and individual stages.

	Data	Algorithm	Programming
Selection phase (Class-level data)	52%	52%	67%
Selection phase (Student-level data)	29%	47%	67%
Individual challenge	79%	63%	66%

To make the ICL a learning opportunity for all participating classes, we provided feedback to each class about their own results. The feedback provided the class with an analysis of the level of proficiency achieved in each computer area. Specifically, the document offered a visual analysis of the data with radar charts at both the scope and individual question levels. Finally, it contained solutions and explanations of the exercises.

5 Reflection Phase for University Students

The experiential learning activity for the University students was concluded by a meta-cognitive [12] activity in which they were guided in reflecting on the experience. Specifically, after the conclusion of the experience, and through an anonymous Wooclap survey they were asked to answer some open question, e.g., to illustrate the hardest, the most useful thing and the learning outcome of the experience.

In addition, they were asked to evaluate on a Likert scale (1–4): the challenge level of the tasks they were involved in; the level of support offered by teachers, classmates, and the quality of the learning resources used to complete the tasks. The experience was perceived as challenging (all answers were 3 and 4) but students perceived to have been supported enough (87,5% of answers were 3 and 4) during the entire activity. The answers to the open questions were discussed in a final meeting, clustering individual answers to open questions, and identifying them as disciplinary, pedagogical, or soft skills. According to the obtained answers, the main skills recognized by the students to have been achieved or strengthened by experience are:

- Disciplinary skills:
  - Creating content aimed at middle school.
  - Matching CS knowledge and the topics required by the syllabus.
- Pedagogical skills:
  - Focusing on the specific skill/knowledge assessed by a question.
  - Formulating questions adequate to the target.

- Soft skills:
  - Teamwork and project management.
  - Inventiveness and creativity.

In the same metacognitive final feedback, the main difficulties related to the experience emerged as formulating clear and unambiguous questions and linking the questions to the Agenda 2030 objectives. Indeed, although the added value of an interdisciplinary approach was well recognized, the need to involve domain experts as advisors and/or reviewers emerged. Although the online management of the challenge was not simple, this was not perceived as a difficulty by the students. Being part of a bachelor's degree course, the proposed activity was a great opportunity for students to discuss their experiences, to propose and test their work to a real audience, therefore empowering their soft skills, and for instructors to establish a sense of trust and openness with students according to the experience-based learning criteria proposed in [13] and, specifically, concrete experience, active experimentation, and reflective observation.

6 Conclusions

In this paper we have described the results of a successful collaboration between university instructors and students in the organization of a distance laboratory on computational thinking. The ICL event enabled multiple levels of learning for all the involved actors: university students and instructors and school classes and teachers. University students had the opportunity to experiment nonstandard education methodologies learnt in the ICDD course in a real scenario and to acquire knowledge on the guidelines for teaching computer science in schools by formulating questions and referring them to the CINI syllabus. University instructors collect useful feedback on the different areas covered by the syllabus and on the format adopted for this kind of orientation events. For school students and teachers, it turned out to be a good opportunity to evaluate computer science competences in a less traditional context. A similar activity has been offered in a remote laboratory with four classes organized in the Pisa Internet Festival in October 2022. The ICL experience was also a turning point for the organization of the contents of the ICDD course that is now based on a series of lectures and activities centered around different type of learning methodologies in which university students must take an active role.

Among future research goals we plan to explore other nonstandard formats to combine computational thinking and digital competences in engaging activities and to refine the evaluation method used for measuring the learning outcomes of university students that got involved in this kind of activities.

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Digital Wisdom Development and Self-reflection of Teacher Candidates

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Abstract. Being digitally wise allows today's students not only to strengthen their natural abilities through existing technologies, but also to respond appropriately to learning networks that are increasingly complex. As a result, it is crucial that teachers and educators continually update and expand their professional knowledge base and improve their practices in order to meet the learning needs of their increasingly diverse students.

The research has been conducted during the academic year 2021–2022 with the participation of 1173 teacher trainees enrolled in the Primary Education Degree Program at the University of Palermo. The trainees carried out their activities through digital tools. Brown and Green's Wisdom Development Scale (2006) tool was used to measure eight factors of wisdom development - across 79 seven-point Likert-type scale items: *self-knowledge, emotional management. Altruism, judgement, inspirational engagement, life knowledge, life skills and willingness to learn.* In addition, some items were selected from the SELFIE for Teachers Tool to help student teachers to review and get feedback on how they are currently using digital tools and technologies for their future profession.

Keywords: Digital wisdom development · Self-reflection · Initial Teacher Education

1 Introduction

Given the increasingly digital nature of our societies, an educational planning that intends to develop the technological competence linked to the concepts of digital wisdom and digital citizenship becomes essential [1].

No doubt that information technology is a fundamental and innovative revolution that has touched human life considerably in the last century, indeed it has just been exploited in all aspects of life, including the educational field [2]. As a result, today's world requires students to have skills, knowledge and abilities in technology, media and information, learning and innovation skills as well as life and career skills [3]. At the same time, the education in this era is expected to obtain graduates who are competent

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in terms of utilizing digital technologies but also competent in literacy, critical thinking, problem solving, communication, collaboration, and have good character quality [4].

On the other hand, the increasing online risks raise ethical questions about how to use digital technologies in a critical, competent and responsible way with users required to engage in processes of moral decision-making online, from observing copyright laws to navigating forms of incivility on social media platforms [5, 6].

This way of experiencing technologies identifies a relationship in which there seems to no longer be the distinction between being connected or disconnected; technologies, in fact, have pervaded our daily life so much that they are invisible. This leads to a reality in which the Internet has changed the way in which knowledge, information and services are produced, consumed and exchanged, also modifying the way of expressing emotions [7, 8]. As stressed by Ferrés & Piscitelli, digital culture therefore requires the development of different skills and abilities, both instrumental and cognitive, intellectual, socio-cultural, axiological and emotional [9].

2 Theoretical Framework

2.1 The Importance of Self-reflection in Teaching

Self-reflection is an ultimate prerequisite and core competency associated with wisdom. According to Weststrate wise people differ from others mainly in terms of why and how they reflect on their past, rather than how much they reflect [10]. Compared to others, wise people engage in an exploratory, self-critical, and non- defensive mode of self-reflective processing that is aimed at deepening their self- insight and fosteringa more complex and realistic understanding of human life.

Finlay defines reflective practice as "learning through and from experience towards gaining new insights of self and practice". All teachers know that self-reflection is an extremely crucial part of the profession as it is the key to their self-awareness. It allows them to look more neutrally at their thoughts, feelings, emotions and actions. Through this practice, teachers and teacher candidates are able to look at themselves with more interest and curiosity by helping to learn, develop, appreciate and understand themselves and their profession [11].

The benefits of self-reflection enable teachers and trainee teachers make sense of their day-to-day experiences, come to decisions, create a course of action to move forward, challenge themselves to switch off from their habitual ways of 'just doing', learn from their experiences and crucially take this learning into the future, realise where they may want to develop and improve next time, realise where and how they use their personal and methodological skills and attitude successfully.

Practicing self-reflection can allow teachers to recognize and make changes not only to mature in their profession but also to grow as a person. To this end, as Rieckhoff and her colleagues strongly suggest pre-service, teacher candidates and in-service teachers need tools for self-reflection and strategies to facilitate and understand the context, culture, and identities of their students within the classroom and society [12].

2.2 Digital Citizenship and Wisdom Development in Initial Teacher Education

Today we all interact using various technologies and this interaction has created a digital society that affords its members opportunities for education and social interaction. According to Sillat and his colleagues, while the concept of digital competence was once considered mainly to comprise skills related to computer use, today the concept refers to a wider sense of knowledge, skills, and attitudes that are largely affected by the labor market [13].

Most of today's students are entirely comfortable with technology. However, a minority of them use it appropriately or understand their roles and responsibilities in digital society [14].

Mossberger and Tolbert defines digital citizenship as the ability to participate in society through digital means and depends on aspects including access to technology, digital skills and wider issues of inclusion and inequalities [15]. Numerous digital competency models and frameworks have been developed for different target groups. In European context, most remarkably these include the DigComp Frameworks for Citizens [16]. Moreover, the UNESCO ICT Competency Framework for Teachers. [17] aims to help countries to develop comprehensive policies and standards for teachers. The DigCompEdu framework was published late 2017 with the aim of creating standards for evaluating the digital competence of educators in Europe [18].

Promoting Digital Citizenship Education is perceived across multiple countries in the world as the most pressing global challenge of the digital age, over both the tackling of online risks such as cyberbullying and issues of digital divide [19, 20]. Schools are adopting strategies that promote character by encouraging adolescents to engage in conversations about the qualities necessary for using digital technologies as citizens of thedigital age. The Council of Europe have provided useful resources to promote both a character and a competencies approach to digital citizenship education [21]. Harrison's analysis of some frameworks shows they all draw implicitly on moral theory [22].

The nine-component framework outlined by Ribble places a strong emphasis on character, virtue and teaching young people to make autonomous decisions [14]. The Digital Competence Framework for Citizens that introduces eight proficiency levels and examples of use focuses on digital literacy and knowledge of technological use but does include netiquette as one of its components [16].

The tension between online risks and opportunities raises ethical questions about how to use digital technologies responsibly, with users required to engage in processes of moral decision-making online. Recently, in the international literature, the term cyber-wisdom is emerging. Cyber-wisdom is the ability to think critically, autonomously, independently and in the moment, when faced with an online moral dilemma.

In this sense, how we can educate children and young people to make free use of the Internet and through making wise moral judgements to utilise its reach and connectivity to improve the lives of individuals and society more broadly [22].

In the digital age, wisdom is broadly understood as "the capacity to realize what is of value, for oneself and others" [23, 24]. The idea behind cyber-wisdom is that internet users are confronted today with the challenging task of navigating a complex environment that provides both opportunities and risks. For this reason, in this digital age, it isessential to provide children with the ability to make decisions online that are driven by virtues such as honesty and compassion and that enable them to choose the right course of action. Having cyber-wisdom literacy means to understand the nature of multiple virtues online, the ethical dimensions of online opportunities and risk, such as understanding the value of accessing a wide range of information online in ways that are emphasized by virtuous curiosity, while reducing the spread of online misinformation, which is amplified by digital technologies, by sharing or producing content in ways that are honest [4].

To sum up, it is essential to promote cyber-wisdom and self-reflection as these terms refer to the ability to reflect on the moral dimensions of one's own experiences online in ways that are grounded in awareness of one's own biases and how these can clash with the perspectives of others, and the ability to regulate one's own emotions (e.g., when experiencing moral dilemmas online) and to navigate the emotions of others.

3 Methods

This study makes use of an exploratory survey to explore student teachers' awareness of their digital skills and to measure eight fundamental factors in their wisdom development. The focus of the research was decidedly pedagogical: therefore, the main purpose was not to determine statistical averages regarding the dimensions of wisdom, but rather to push for a reflection that could lead in the future to a didactic-educational design which takes into account the pluralistic and conflictual feature of the media system and to enhance students' digital competencies by contributing to their digital wisdom development.

3.1 Sample

During the academic year 2021/22 an exploratory survey was conducted with a sample of 1173 trainee students attending the Primary Education degree course at the University of Palermo (Fig. 1).

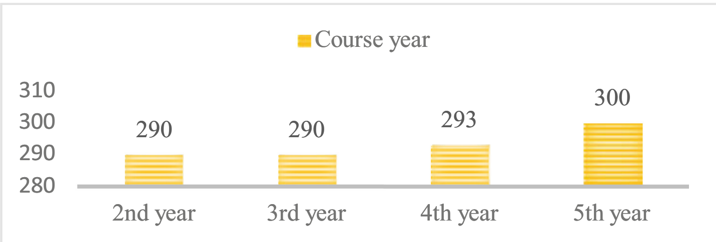

Fig. 1. Participants per course year

4 Data Gathering Tools

The survey was conducted using two tools with different exploratory purposes: Brown and Green's Wisdom Development Scale (2006) and the SELFIE for Teachers tool, which has DigCompEdu as its reference framework. The survey allowed us to verify the degree of awareness that students have about their digital skills and to measure eight fundamental factors of wisdom development. The choice to integrate these two tools arises from the awareness that developing a wise attitude in the various dimensions of existence can lead to the continuous reflection of one's own practices, a wise person knows how to use technologies to enhance his intelligence, to find the most effective responses to complex problems, doing it with a critical sense, awareness and responsibility towards the effects that the use of these technologies could derive for others.

4.1 Wisdom Development Scale (WDS)

The Wisdom Development Scale (WDS) is designed by Brown and Green (2006) to measure a person's level of self-knowledge, emotional management, altruism, judgment, inspirational engagement, life knowledge, life skills and willingness to learn. In this study, the use of WDS aims at guiding students to reflect in order to promote their maturation and sensitize them to the above stated factors. It describes wisdom, how wisdom develops and the conditions that facilitate wisdom development. Moreover, it aims to investigate what students gain from their educational experiences. Specifically, it measures eight factors that are considered fundamental for the development of wisdom through a seven-point Likert-type scale ranging from Strongly Disagree (1) to Strongly Agree (7):

- *Self-Knowledge* describes how well a person knows his or her own interests, strengths, weaknesses, and values.
- *Emotional management* and *altruism* describe a person's deep understanding of a wide variety of people in varying contexts, a genuine interest in learning about others (attentiveness, empathy), the capability of engaging them (various approaches), a willingness to help them, and possession of advanced communication skills that enable one to articulate thoughts in a way meaningful toanother person.
- *Judgment* refers to the knowledge that there are different ways of looking at an issue when making key decisions, and that one must take into account a variety of viewpoints, the past, and the present context, as well as one's own background influences.
- *Inspirational engagement* and *life knowledge* are characterized by a capacity to grasp the central issue, find one's way in a time of darkness, and understand the realities and uncertainties of life, over the life span.
- *Life Skills* includes the ability to manage one's daily multiple roles and responsibilities effectively. Life Skills is practical competence, an ability to under- stand systems and anticipate problems, with tools and strategies for dealing with multiple contexts in life.
- *Willingness to learn* describes a basic humility in what one knows and continual interest in learning about the world.

The WDS can help researchers identify whether individuals are developing wisdom and what intrapersonal factors and experiences are affecting it. It can indicate which types of experiences seem to be most likely to promote the development of wisdom in all aspects of human activity. These experiences can include school, relationships, community engagement and these factors could help design more integrative and holistic learning experiences.

4.2 SELFIE for Teachers

Designed and launched by European Commission (2021), SELFIE for Teachers Tool aims at helping educators and teachers reflect on how they are using digital technologies in their professional practice. Teachers can use the tool to learn more about the digital skills they have and identify areas where they can develop further [25]. In this study, seven items of the instrument were selected as they are in line with the activities carried out by the trainees in remote mode and therefore essential to bring students to reflect on their practices:

- *Managing online learning environments taking data management and ethics into account.*
- *Using searching and selection criteria to identify digital resources for teaching and learning.*
- *Creating digital resources that support and enhance teaching and learning aims.*
- *Sharing digital content with respect to intellectual property and copyright rules.*
- *Designing, developing and support learning with the use of digital technologies to enhance learning outcomes.*
- *Using digital technologies to foster and enhance learner collaboration for individual and collective learning*
- *Using digital technologies to enhance students' self-regulated learning processes, fostering active and autonomous learning making students more responsible for their own learning, thereby shifting the focus from teaching to learning.*

As a tool and associated reflection process, SELFIE for Teachers is designed to support systematic and transparent development of ongoing practice through reflection, thereby improving student, professional and organizational learning. SELFIE can enable school communities to periodically self-reflect on their progress and help them plan future steps in realizing effective digital-age learning.

5 Results and Discussions

5.1 Wisdom Development Scale

This section analyzes four of the eight factors that the Wisdom Development Scale investigates. Specifically, we wanted to measure a person's level of *emotional management*, *judgment*, *life knowledge* and *life skills*. The data collected show high levels of agreement of the respondents with all the factors analyzed. The emotional management factor describes the attention and empathy towards others, how much one is willing to involve and help them. It also investigates the level of emotional management in stressful situations; in the case of stress management, students declare that they are partiallyable

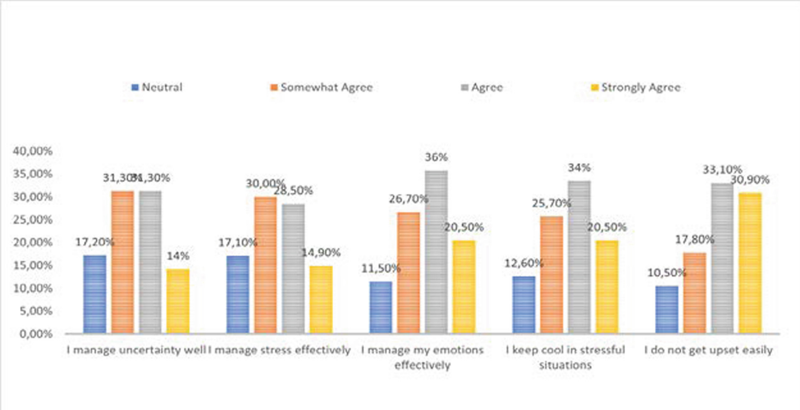

Fig. 2. Emotional Management

to manage it effectively (30%), only 14,9% declare that they strongly agree with the statement presented (Fig. 2).

The altruism factor describes the attitude of openness towards others, the willingness to help and involve them, but also the solidarity we show towards others. Students' responses show a very strong agreement in treating others with respect (83%), but also in helping others, in accepting and respecting the needs of others. The only claim in which there is a minor agreement is to make amends when one hurts someone, as it could testify to a difficulty in admitting one's mistakes (Fig. 3).

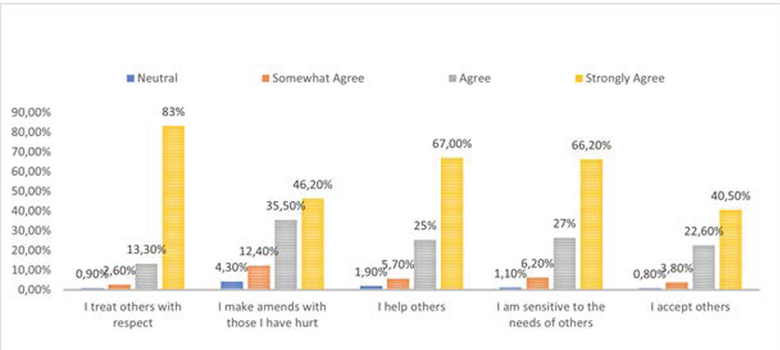

Fig. 3. Altruism

The ability to judge concerns the awareness of knowing how to adapt one's behavior in different situations and the importance of integrating and applying knowledge in different life contexts. Most of the students are strongly aware of the importance of context when making a decision (51,5%), but report having less awareness of how to behave ina variety situations (37,40%). Finally, 59% of students declare that they show curiosity in various life contexts, which presupposes a non-judgmental attitude towards others (Fig. 4).

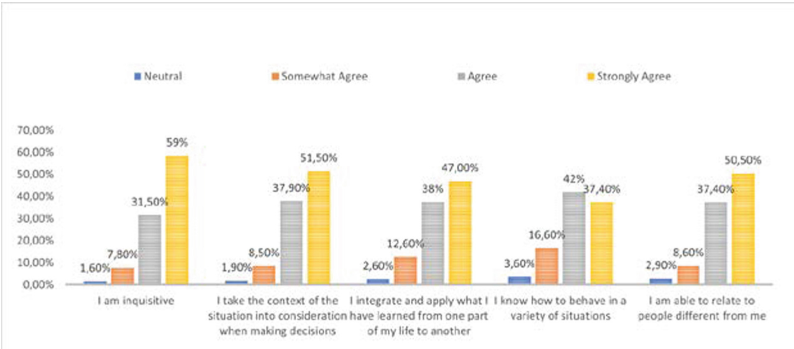

Fig. 4. Judgement

Figure 5 shows the students' responses to some items of the life knowledge factor. This factor measures the awareness on the uncertainties in life and aspects that cannot be changed. Students report that they regularly reflect on their life (55%), but there is no strong acceptance of life's uncertainties.

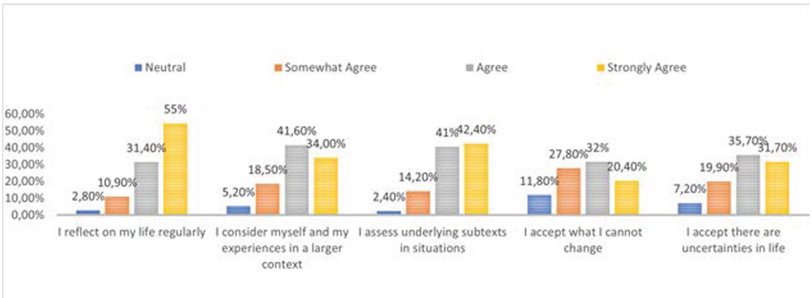

Fig. 5. Life Knowledge

Regarding life skills, 53.9% of students report they have a sense of purpose in life, as it comes with strong agreement in affirmations about achieving their goals (35,80%) and effectively managing time to give priority to their projects (33%). Positive scores are also recorded in making healthy decisions and in the awareness of being multitasking and, therefore, of being able to manage different activities at the same time, maintaining a high level of attention.

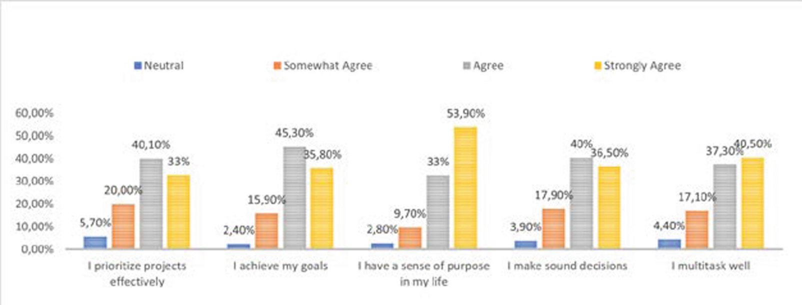

Fig. 6. Life Skills

Wisdom is a complex concept which makes it quite difficult to explore. The items proposed to the students were intended to be a part of a reflection exercise that would stimulate them to reflect on different aspects of their life. Becoming aware in emotional management or judgement, reflecting on life skills and life knowledge has led them to reflect on their past life experiences and will likely lead them in the future to develop reflective thinking in different contexts, even when facing problematic situations in digital environments.

We are aware of the fact that the WDS tool investigates the factors of the development of wisdom, but in today's society there is a need to investigate the wisdom manifested also in digital environments. Starting from this exercise of reflection, we want to investigate more on the development of a tool that is able to measure the level of wisdom in the different contexts of today's life.

5.2 SELFIE for Teachers

Through the seven items of SELFIE for Teachers tool (selected from different areas), the students' opinions on the use of technologies in their practice were collected. These were at the same time the sources of a reflection exercise on the conscious use of technologies.

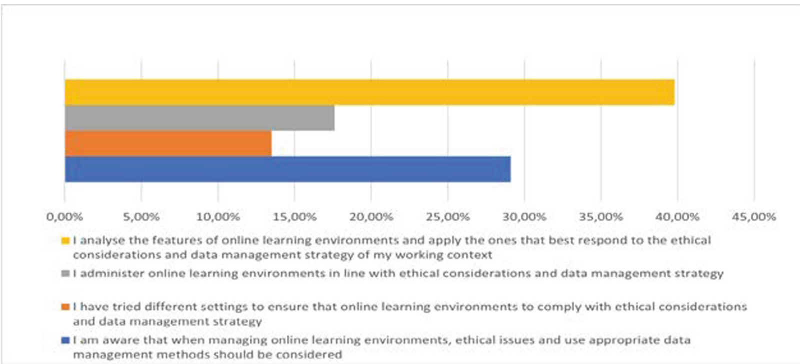

Fig. 7. Professional Engagement – Online learning environments

As regards the management of online learning environments, most of the participants state that they analyze the functionalities of these environments in order to be able to apply in practice those that most reflect ethical considerations. In fact, 39.8% apply data management strategies to promote ethical conduct (Fig. 7).

As regards the search and selection criteria in identifying digital and online resources, students declare that they use different tools and portals to use resources that are in line with the different educational needs (39.7%); however, only a small part (3.4%) indicate to reflect on online searches and then adapt them to different contexts (Fig. 8).

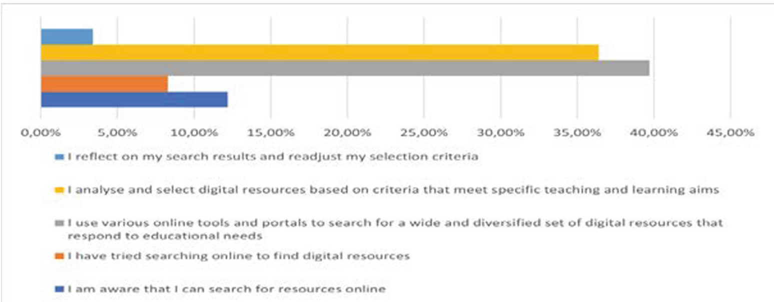

Fig. 8. Digital Resources - Searching and selecting

As for the creation of digital resources to improve teaching and learning objectives, 48.3% of trainee students are careful in selecting the tools that best meet their learning needs. Only a small percentage (6.9%) declare that they pause to evaluate and adapt them based on the feedback received (Fig. 9).

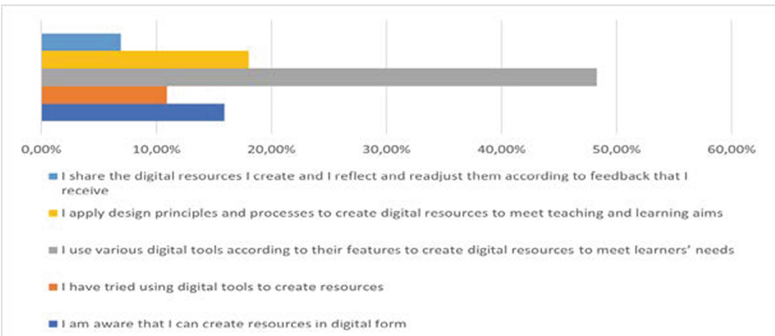

Fig. 9. Digital Resources – Creating

When using digital resources, 41.3% of students are aware that intellectual property and copyright rules should apply to them, but only 10.7% actually state that they apply these rules when sharing digital assets created (Fig. 10).

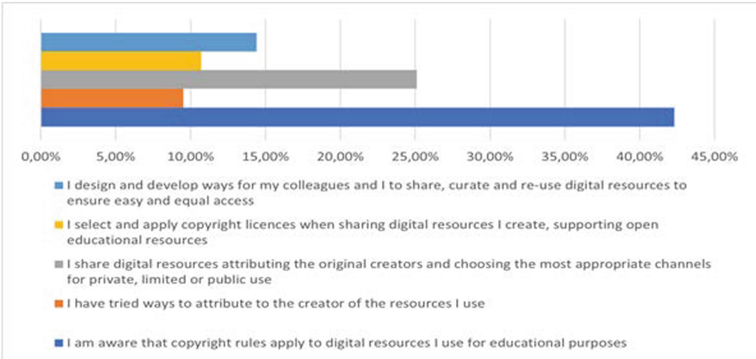

Fig. 10. Digital Resources – Sharing

Regarding the design, development and carrying out of activities with technologies, 38.7% use them to improve the active participation of students, in line with innovative pedagogical approaches, even if there is little reflection and redesign of the on the basis of the results obtained (9.7%) (Fig. 11).

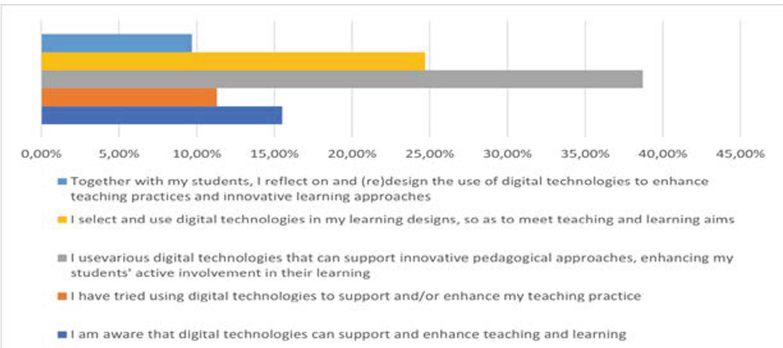

Fig.11. Teaching and Learning - Teaching

40.3% use digital technologies based on their functionalities to foster and support collaborative learning, but only 6.6% reflect on the use of these tools and redesign them for individual or collaborative learning (Fig. 12).

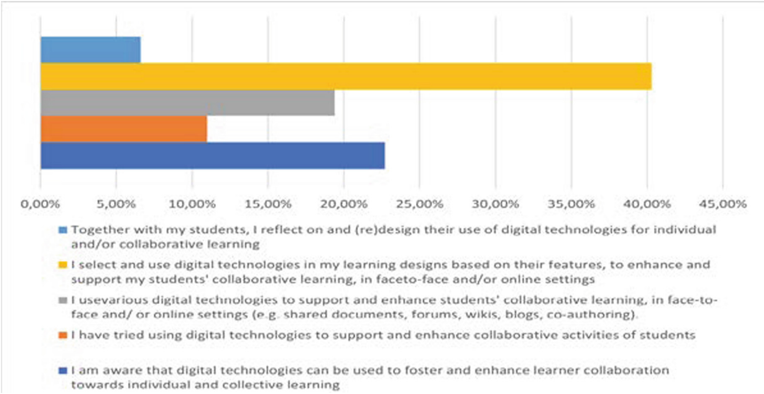

Fig. 12. Teaching and Learning - Collaborative Learning

Finally, 38.4% choose and use digital technologies based on their functionalities to foster self-regulated learning skills (Fig. 13).

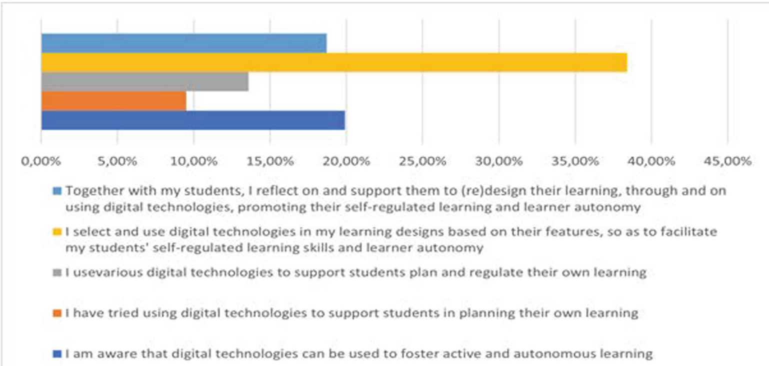

Fig. 13. Teaching and Learning - Self-regulated learning

6 Conclusion

In this digital age, wise students must possess cognitive knowledges and skills that al low them to face the complexities arising from online environments so as to be able to show creativity and critical thinking and be able to recognize the potential of an online resource. Being digitally wise allows not only to strengthen one's skills through existing technologies, but also to respond appropriately to the challenges of increasingly complex learning.

The challenge that the researchers face is therefore to claim the superiority of the didactic pedagogical model over the technical one inherent in the technological tool, so as to be able to transform digital media into individual and social empowerment tools.

It is essential to offer students skills-based learning that considers citizenship education an essential element to build critical, responsible and ethical citizens who are active and aware inhabitants in the society of the future.

From the theoretical framework and the survey conducted, the need for greater reflection on the ethical implications in the use of technology emerges. Following the exploratory investigation, a crucial question arose whose answer will be the basis of future research. What kind of wisdom do users need to develop in the digital age and how to investigate such a complex construct?

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Promoting Leadership Skills in Teachers with Coaching

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Abstract. Today, the acquisition of additional skills by the teacher is a central factor in addressing contemporary changes in educational practices. Parallel to this, teaching profession requires an identity and practical teaching skills to improve the ability to help the younger generation in their self-realization. As a result, the teacher is no longer just a disseminator of knowledge, but a professional committed to consolidating his/her profile through paths of training and cultural growth, participation in experiences that intertwine teaching activity, with multidisciplinary design, educational research and ongoing training. Taking a closer look at how coaching can support teachers' development, this study aims at exploring how teachers' knowledge can be expanded through coaching, and understanding how coaching can be an educational, relational and motivational competence. So, we should seek answer to the following question: What is the better way to invest in the professional learning of teachers? Having a reflective approach to help the teachers develop skills naturally reinforces their inner doubt and dissatisfaction regarding what they do, which in turn encourages them to reflect on their actions, play the role of the researcher in collecting data, and use critical thinking to reach a deeper understanding of the problem, and thus develop appropriate solutions for it. For this reason, the paper aims at analyzing the empowerment of leadership skills and soft skills of teachers through an individual coaching intervention because a range of contemporary publications forcefully argue that teachers should play a far more central role in decision making and policy formation.

Keywords: Coaching · Teachers' leadership · Professional competence

1 Introduction

Our work starts from the observation that teachers are not adequately prepared to face the change and the critical issues that derive from today's complexity.

New skills are always required and for this reason we believe it is crucial to train new teachers in Teachers' leadership skills and soft skills already in the university environment. It is not possible for schools to stay out of change in the rapidly changing world with the effect of globalization.

The authors L. Longo, V. Di Martino and F. Martino contributed equally to this work. In particular, L. Longo wrote the Sects. 1, 3; V. Di Martino wrote the Sects. 4, 5 and F. Martino wrote the Sects. 2.

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In this case, schools will continue their lives as organizations that are either only affected by their environment or affect their environment by being integrated into change. Effective implementation of innovation initiatives in schools depends on the participation of teachers as practitioners in these processes and the creation of new behaviors for teachers. In this context, it is crucial to support teachers' leadership behaviors and to create leadership behaviors in teachers [1, 2].

Teachers need special skills to be effective leaders [3, 4]. Leader teachers need development in the dimension of reflecting their talents in order to evaluate their own views and practices. They need development in terms of communication and facilitation in order to ensure that the change to be experienced at school takes place in cooperation [5, 6].

Teacher leaders are able to set healthy boundaries to cope with overworking, to regulate emotions, to use assertiveness to respond properly to colleagues, students, and families' demands, and they know how to maximize their strengths in order to minimize hurriedness and time-wasting [7, 8].

Coaching can play a significant role in leadership development because it strongly echoes the process of how adults learn. It seeks to help leaders understand the meaning they bring to their surroundings and the actions they take [9].

Working within the domain of how leaders see the world it strives to build competency development and to leave the leaders self-correcting and self-generating [10]. Coaching provides a structure for the follow up to training that is essential for acquiring new teaching skills and strategies. It can help building communities of teachers who continuously engage in the study of their craft. Coaching is as much a communal activity, a relationship among seeking professionals, as it is the exercise of a set of skills and a vital component of training [11].

Moreover, coaching develops the shared language and set of common understandings necessary for the collegial study of new knowledge and skills. Especially important is the agreement that curriculum and instruction need constant improvement and that expanding our repertoire of teaching skills requires hard work, in which the help of our colleagues is indispensable [12].

After illustrating the theoretical constructs considered for our study, the contribution focuses on the description of the research tools used and the discussion of the first results obtained. Considering the premises presented so far, this paper aims at analyzing the empowerment of leadership skills and soft skills of teachers through an individual coaching intervention in the specific Italian context in which research on these aspects is completely lacking. Specifically, it has been hypothesized that the implementation of an individual coaching intervention, systematically prepared and of increasing complexity, positively affects the growth of leadership skills and soft skills of teachers.

2 Theoretical Framework

2.1 Teachers' Leadership Skills

In recent years, there have been many and substantial investments in the professional development (PD) of teachers in order to enable them to better address the different academic needs of each student. In 2017, the Learning Policy Institute (LPI) reviewed 35 methodologically rigorous studies that demonstrated a positive link between teacher professional development, teaching practices, and student outcomes [13]. LPI found that effective professional development: is content focused; incorporates active learning; supports collaboration; uses models of effective practice; provides coaching and expert support; offers feedback and reflection; is of sustained duration.

In order to consistently provide the kind of professional development that leads to sustained improvements in classroom practice, schools need structures and systems that facilitate a continuous improvement process, instructional leadership positions with responsibility and authority to oversee this process, and teacher leaders who are trained to support adult learning and build trust with the teachers they serve [14].

Teacher leadership is viewed as a powerful vehicle for the improvement of schools, teaching, and learning [15]. The literature on teacher leadership includes a wide variety of definitions of the term, Lai and Cheung [16] state that "teacher leadership consists of three major acts, namely teacher participation in educational improvement efforts, teacher learning in communities of practice and teacher learning beyond the classroom" (p. 676). Teacher leaders, according to Wenner and Campbell [17], assist with professional learning, decision making, student learning, and school change. Five dimensions of teacher leadership described by Muijs and Harris [18] include shared decision making, collaboration, school improvement, professional learning, and activism.

The central proposition is to 'Flip the System' [19–21] so that teachers become the instigators, creators and implementors of educational change.

Teachers as the co-constructors of educational change and key contributors to policy making is an idea that is long overdue in many education systems. Where teachers are genuinely at the forefront of educational reform and co-constructing change, the net result can be both positive and empowering [22].

Similarly, Johnson [23] argue that opportunities to engage in teacher leadership promote job satisfaction and commitment among teachers. Teacher leadership can lead to increased collaboration and responsibility among all teachers, according to Muijs and Harris [24]. Furthermore, Van Veen, Zwart and Meirink [25] identify coaching as an innovative form of professional development in which teachers play an active role.

The most influential reviews of the literature, to date, concerning teacher leadership are those by York-Barr [26] and Wener and Campbell [27]. Both these reviews signal the centrality of teachers influencing the process of school transformation and educational change.

From the literature, the positive personal characteristic of successful teacher leader should be: committed, confident, well organized, communicative, empathetic, flexible, and reflective. As not just empathic toward others, but deeply compassionate toward others; not just committed, but passionately driven to improve teaching and learning; and not just willing to support others, but courageous in their willingness to stand up for others, especially for students.

So, the specific knowledge and skills of teacher leaders are content and pedagogical knowledge, communication skills, collaborative skills, and problem-solving skills. We agree that every teacher should contribute to "a cause beyond one's self" [28] and believe that all teachers have the capacity to provide some type of leadership beyond their classroom. Maybe, the best way to view teacher leadership may be to place teachers on a leadership continuum, with all teachers invited and expected to lead, but with teachers situated at various points on a continuum from less to more capacity and commitment to lead.

2.2 Coaching for Developing Teachers' Leadership Skills

The changes that have affected the school, the autonomy of teaching based on national indications and personalized curricula, with strong changes in the social context, current complexity and uncertainty have gradually changed the profile of the teacher and educational skills. Today pedagogies necessarily look different in different contexts [29] and each context creates unique challenges of implementation [30].

The acquisition of additional skills by the teacher is a central factor in addressing contemporary changes in educational practices. In view of these, the teaching profession requires an identity and practical teaching skills to improve the ability to help the younger generation in their self-realization [31]. Against this backdrop, we view teacher coaching as a promising form of PD for supporting teachers' learning oriented teaching [25]. In this sense, this study examines the demand for coaching in schools as a teaching, relational and motivational competence in the specific Italian context.

From many areas of experience and coaching training we can see how the teacher can progressively exercise the function of motivator, facilitator and inspiration towards his students.

Taking a closer look at how coaching can support teachers' development, Munson [32] illuminated how side-by-side coaching could support teachers' in-the-moment decision-making by making their thinking and noticing visible. Together, these studies provide evidence that coaching can support teachers in developing or adopting more ambitious teaching practices. We recommend that future research not only verify and expand these findings, but also explore methodological and theoretical approaches that look inside coaching interactions to illuminate how coaching can support teachers' learning [33]. Combining such tools with Powell and colleagues' rich framework could uncover yet-unexplored affordances of coaching.

The teacher education programs today are often prepared for the student teachers to help them create a vision to foresee the daily requisites of teaching. In other words, what student teachers often struggle to do is that they install theoretical courses in their teaching [34, 35]. The irony which is seen in the teacher education programs is that when the student teachers are most in need of help in acquiring abilities of reflection and establishing a link between the theory and the practice, they are often excluded from their teacher educator at universities. For the sake of understanding the context of reflective coaching (RC) in our study, we define it as a "guided reflective teaching". In this way, the novelty of this study consists in supporting the introduction of coaching as a tool of PD, also with an in-depth investigation of the choices of cultural and educational models and their organization in view of planning and concrete actions. The teacher thus finds himself rethinking his own role in the more global perspective of training, and this dimension leads to the acquisition of deeper capacities for organizing and carrying out school work.

Through the reflective coaching, the student teachers' concerns will be influenced by their perception of their failure or weakness and their conception of a certain teaching component. The reflective coaches give new teachers a powerful and rich, coaching experience [36] built on their instructional skills and knowledge and enhances sense of efficacy of them [37].

Employing a reflective approach to help the teachers develop them naturally reinforces their inner doubt and dissatisfaction regarding what they do, which in turn encourages them to reflect on their actions, play the role of the researcher in collecting data, and use critical thinking to reach a deeper understanding of the problem, and thus develop appropriate solutions for it [38].

3 Methods

In this section the characteristics of the research sample and the tools used for data collection will be presented.

The study adopts a mix-methods approach using a pretest and post-test design without a control group. The research lasts for three years.

3.1 Sample

A sample of 15 schools was selected for each year. On the basis of their individual availability, for each school the head teacher has identified 4 teachers with staff functions. A total of 60 teachers participates in the experimentation started in the first year.

Each teacher is involved in an individual coaching intervention lasting two and a half months, consisting of 5 individual sessions fifteen days apart.

The sample is composed of 25% male and 75% female with an average age of 49.81 (SD = 7.27).

3.2 Measurement

Two measures were administrated before the coaching sessions and as follow-up (6 months after the end of coaching sessions):

a) Soft Skills Inventory [39];
b) Teacher Perception, Assumptions About Leadership Questionnaire.

For the evaluation of the soft skills of teachers, the Soft Skills Inventory (SSI) questionnaire was chosen, a self-assessment tool of the organizational-managerial and relational skills of the teacher. The tool was built using Tucciarelli's Soft Skills Map; this map has been developed as an assessment tool before starting a training course for those interested not in acquiring technical skills, but rather in improving in one or more soft skills.

The skills map has been designed to provide the broadest possible picture of basic soft skills. The questionnaire is divided into 2 sections (see Table 1):

1. Managerial – strategic skills: they are willing to find solutions to unsolved problems and to apply them; – managerial: they promote collaboration with others to achieve a result together.
2. Relational-interpersonal skills: contribute to the establishment and maintenance of the personal relationship; – communicative: they favor, within a relationship, the mutual understanding of the contents that are intended to be transmitted.

Table 1. Sections of SSI (Soft Skills Inventory) questionnaire

1) Organizational – Managerial Skills		**2) Relational Skills**	
a) Strategic	b) Managerial	a) Interpersonal	b) Communicative
1. Creativity *2. Learning* *3. Planning* *4. Proactivity*	*5. Motivation* *6. Interaction* *7. Mediation* *8. Formation*	*1. Assertiveness* *2. Reception* *3. Trust* *4. Conflict management*	*5. Listening* *6. Mirroring* *7. Feedback* *8. Incisiveness*

The Teacher Perception, Assumptions About Leadership Questionnaire. Consists of 10 items in which teachers are invited to express their perception of leadership on a scale of 1 to 5 with respect to two antithetical statements.

At the end of the 5 individual coaching sessions, each teacher was involved in a focus group (10 participants) which aimed to investigate the teacher leadership competencies in four domains according to Teacher Leaders Self-assessment Framework (see Table 2). Each domain includes several competencies: some are foundational, for teachers who are beginning to think about leadership roles, and others are advanced, for teachers who are already taking on leadership roles. Each competency is divided into several indicators that include possible evidence and look-fors to consider.

Table 2. Domains of Teacher Leaders Self-Assessment Framework.

1) Collaboration and Communication		**2) Professional Learning and Growth**	
Foundational	Advanced	Foundational	Advanced
1.1 Developing Positive Relationship and Trust	1.3 Group Processed, Facilitation and Coaching Skills	2.1 Ongoing Self-Development	2.3 Understanding Adult Learning
1.2 Listening Skills	1.4 Listening Skills	2.2 Ongoing Self-Reflection	2.4 Facilitating Professional Learning Among Colleagues

(*continued*)

Table 2. (*continued*)

3) Instructional Leadership		**4) School Community and Advocacy**	
Foundational	Advanced	Foundational	Advanced
3.1 Demonstrating Pedagogical Knowledge	3.5 Using Data and Research to Improve Practice	4.1 Supporting and Strengthening the School Community	4.2 Demonstrating Systems Thinking
3.2 Beginning Coaching Skills	3.6 Applying Coaching Skills		4.3 Building Partnerships
3.3 Demonstrating Social and Emotional Competency			4.4 Involvement in School Improvement
3.4 Understanding Data and Research			4.5 Professional Advocacy

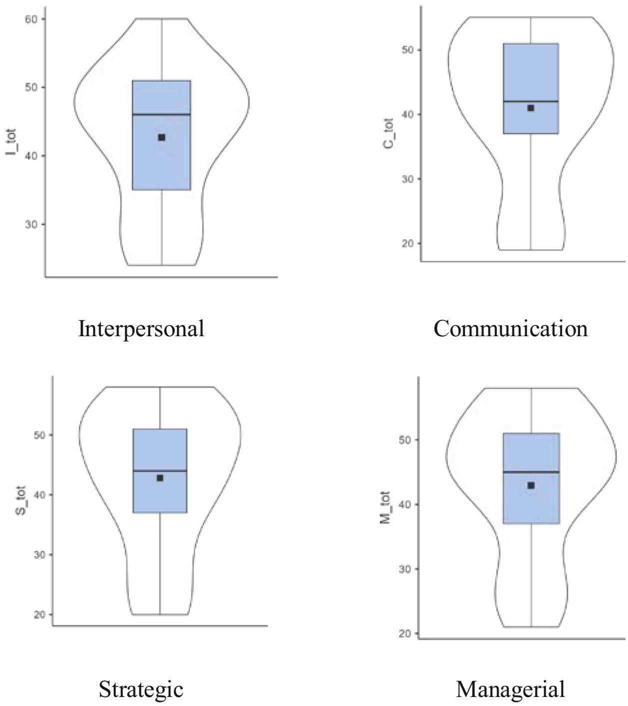

Fig. 1. Violin plot related to Soft Skills Inventory Scales.

4 Preliminary Results

From the analysis of the data relating to the Soft Skills Inventory, higher average scores emerge on the scales relating to organizational-managerial skills (M = 85.8, SD = 23.3) compared to relational skills (M = 83.6, SD = 22.5).

More specifically (see Fig. 1), very similar average scores are found in the scales relating to strategic skills (M = 42.8, SD = 12.2) and managerial (M = 42.9, SD = 11.4). In the context of interpersonal skills, the average score for communication skills (M = 41.0, SD = 12.1) is lower than the average score for interpersonal skills (M = 42.6, SD = 10.6).

Data from the Teacher Perception, Assumptions About Leadership Questionnaire (see Table 3) show that 94% of teachers (options 4 and 5) think that "Teacher leaders work as collaborative individuals" (9b), 74% (options 4 and 5) states that "Schools need leadership from teachers" (1b), while 69% (options 4 and 5) believe that "Teachers leaders may emerge unexpectedly" (5b).

Furthermore, 87% of teachers (options 1 and 2) declare that "Teacher leaders have pedagogical credibility" (8a), 69% (options 1 and 2) state that "Teacher leaders are popular with colleagues" (10a), while 56% (options 1 and 2) are convinced that "Teacher leadership is distinctive" (2a) and that "Teacher leadership can be nurtured" (7a).

Table 3. Percentage frequencies related to the items of the Teacher Perception, Assumptions About Leadership Questionnaire.

	1	2	3	4	5	
1a. Schools do not need teacher leadership	0%	13%	13%	37%	37%	1b. Schools need leadership from teachers
2a. Teacher leadership is distinctive	19%	37%	13%	25%	6%	2b. Teacher leadership is like other forms of leadership
3a. Teaching, learning and assessment are the focus of teacher leadership	25%	25%	12%	19%	19%	3b. Organizational issues are the focus of teacher leadership
4a. Teacher leadership is enduring and sustainable	19%	31%	19%	31%	0%	4b. Teacher leadership is episodic and situational
5a. Teacher leaders are identifiable through scientific and personality analysis	0%	25%	6%	44%	25%	5b. Teachers leaders may emerge unexpectedly
6a. All teachers are potential leaders	18%	13%	13%	25%	31%	6b. Some teachers are potential leaders
7a. Teacher leadership can be nurtured	31%	25%	19%	19%	6%	7b. Teacher leadership is inherent

(*continued*)

Table 3. (*continued*)

	1	2	3	4	5	
8a. Teacher leaders have pedagogical credibility	56%	31%	13%	0%	0%	8b. Teacher leaders do not need to have pedagogical credibility
9a. Teacher leaders work as individual professionals	0%	0%	6%	19%	75%	9b. Teacher leaders work as collaborative individuals
10a. Teacher leaders are popular with colleagues	31%	38%	19%	12%	0%	10b. Teacher leaders are seen as difficult by colleagues

The focus groups were conducted at the end of the coaching sections on the basis of the four domains identified by the Teacher Leaders Self-assessment tool. The focus group sessions were audio-recorded, transcribed and analyzed using the MaxQDA software.

With reference to the Collaboration and Communication domain, the teachers highlight how the coaching sessions made it possible to reflect on the conditions necessary for the creation of a positive and protected climate in which all teachers have the opportunity to assume their responsibilities and share their own experiences. It is also highlighted how in this climate it is easier to share different opinions and constructively identify alternative solutions based on different perspectives. In some cases, it is reported that the coaching sessions were an important opportunity to work on one's limits and on the possibility of apologizing, if necessary, thus helping to build authentic relationships. At a more advanced level, the facilitation of group dynamics also emerges, exemplified by some teachers in organizing effective meetings, also through the use of technology, increasing the active involvement of all colleagues. From what was reported by the teachers, coaching has influenced the resolution of conflicts between colleagues, also thanks to the mediation action between multiple points of view.

In relation to the Professional Learning and Growth domain, the teachers report that coaching has triggered in them a process of continuous self-reflection and a growth mentality, as well as the desire to share what they have learned with colleagues, encouraging them in professional development paths. At a more advanced level, some teachers come to the need to create "a culture of collegiality" and are willing to investigate the results of recent research that have dealt with these issues.

Compared to the more specific domain relating to Instructional Leadership, a pedagogical dimension strongly emerges linked to crucial issues for learning, such as the quality of teaching, the effectiveness of teaching interventions, the multiple methods of evaluation, active involvement of students, attention to socio-emotional dynamics, issues related to equity and inclusion. The teachers point out that it is these characterizations that determine the peculiarity of teacher leadership with respect to other forms of leadership. However, it is interesting to point out that the possibility of using data and research to improve practice appears to have been delegated to others. This is an area on which the world of research itself should question itself and which could find answers in the Evidence Based Education approach.

Finally, with reference to the domain of the School community and Advocacy, the teachers believe that the coaching path has helped to support and strengthen the sense of belonging to the school community. In this regard, they report examples that can be traced back to a more active participation in school initiatives, expressing interest in taking charge of the efforts for the improvement of the school. They also declare that they have acquired a systemic thinking, broadening their perspective from the single school reality to a regional, national and international level.

5 Conclusions

Analysis of the results shows that coaching sessions have a positive impact on improving both leadership skills and soft skills of teacher leaders, with particular reference to communication and relational skills, initially highlighted as lacking. Positive repercussions are also pointed out with regard to a higher executive effectiveness in teacher leaders' practices and a better ability to achieve the programmed objectives, as well as on the climate of the school community itself. It will be interesting to check whether the reflections on the strengths and weaknesses that emerged during the focus groups will persist even during the follow-up, together with an increase in soft skills and positive perceptions of teacher leadership. In further research it could be interesting to use the intervention model and the detection tools developed with respect to other types of coaching highlighted by the literature, such as the peer coaching-based professional development approach [40] and possible integrations between in-person and virtual coaching [41].

Finally, the findings from this study may be useful for both educational and scientific purposes and they encourage proceeding with a larger study to evaluate coaching intervention's effectiveness on leadership and soft skills and dispositions. It might also be interesting to investigate which leadership skills should be acquired starting from the initial teacher training courses.

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Coding Maps: A Distance Laboratory on Computational Thinking Inspired by Modal Logic

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Abstract. We present the Coding Maps project carried out by a team of students and teachers of the Computer Science Bachelor's degree of the University of Genoa, aimed at the creation of a computational thinking distance laboratory for the 2021 edition of the Genoa Science Festival. The main challenge for the team was to create an activity that could be engaging for students of different ages (middle and high school) exploiting the digital skills on remote learning acquired during the pandemics. The team adopted the metaphor of gamification and interactive applications via an online multiplayer platform in combination with more traditional computer science orientation approaches based on computational thinking and problem solving. The structure of the proposed activity was inspired to non standard logic languages such as modal logic and the corresponding possible worlds semantics in which the truth of an assertion depends on the accessibility relation among different worlds.

Keywords: Digital skills · Teamwork between students and teachers · Computational Thinking · Distance Learning · Gamification · (Modal) Logic

1 Introduction

In this paper we present the Coding Maps project [6] carried out by a team of students and teachers of the computer science bachelor's degree of the University of Genoa, aimed at the creation of a computational thinking distance activity, that was then run as a distance lab in the 2021 edition of the Genoa Science Festival. The Genoa Science Festival is a well known scientific event in Italy, run yearly since 2003, with the University of Genoa as a partner. It consists in twelve days of scientific activities (labs, conferences, exhibits, and shows) located in different areas of the city. During the pandemics (2020 edition), the Festival started offering several distance activities including seminars and labs. The 2021 edition attracted 50 thousands visitors, among which 13 thousands students, and 120 thousands online visitors. The Coding Maps DigiLab was offered as an alternative to the face-to-face coding labs organized by the authors (using visual languages like Scratch and Pocket code) in the Festival editions before the pandemics.

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The main challenge for the team was to create an online laboratory that could be engaging for students of different ages (middle and high school) making the most of what we learned (both as teachers and as students) in the distance learning experience during the pandemics. For this purpose, the team decided to adopt the metaphor of gamification and interactive applications [1,8] via the online game platform Smart O.C.A. [3] in combination with more traditional computer science orientation approaches based on computational thinking and problem solving [5,9]. Computational thinking [9] involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science, such as breaking down problems, abstract thinking, algorithmic lens for formalizing solutions.

The setting of the Coding Maps game was a planetary journey during which participants faced questions and solved problems associated with basic computational concepts presented in four different galaxies: logic, control flow, variables, and input/output. Space exploration has been selected to design an inclusive activity, aimed at reducing the gender gap in introductory coding activities [7]. The idea of considering a set of worlds (the map), an accessibility relation between worlds (what astronauts could see after landing), and logic statements associated to each world was inspired to non standard logic languages like modal logic and to the possible world semantics proposed by Saul Kripke [4], see also [2,10].

Every question proposed to participants within a galaxy presented a different type of difficulty: notion understanding, reasoning, programming, etc. The first two groups of questions, logic principles and control flow, were related to propositional logic, first-order statements and to basic programming constructs such as repetition and alternative. Logic has a strong correlation with natural language, making it a perfect transition topic from "human thinking" to "computer thinking". Control flow such as if-then-else and repeat statements were used to implicitly present the concept of algorithm. These groups of questions were also related to the idea of breaking down problems and solving them using the basic constructs. The third galaxy introduced the concept of computer memory, implemented using variables. Finally, the concept of input/output was introduced by using the metaphor of communication between astronauts (the participants) and a base station on planet earth. Even though this interaction is only simulated, it's enough to give an intuition of what a flow of information means in a computer system. Correct answers allowed participants to receive additional information to continue their journey moving from galaxy to galaxy, and from planet to planet. Additional explanations were given in case of wrong answers. The last quizzes of the game, with increasing difficulty, required to reuse concepts introduced during the journey. This way, students had the opportunity to apply the knowledge they had just acquired. The project was developed and hosted on the Smart O.C.A. platform [3], a game design application developed by the Edutainment Formula company in the context of a collaboration with our team.

The Coding Maps project has been offered as a DigiLab in the program for schools of the Genoa Science Festival. Several computer science students entered our team as tutors to conduct online the lab with the registered classes. In total 370 online participants took part in the activity in the different time slots in which it was offered. The project required a lot of efforts and allowed the entire team (both students and teachers) to improve their digital and soft skills. More specifically, designing and conducting the laboratory during the Science Festival allowed the team members to experiment a non-standard combination of technologies for distance learning, online games, and polls with more traditional computer science orientation approaches.

Plan of the paper. In Sect. 2 we present the software platforms used for creating the digiLab. In Sects. 3 and 4 we describe in detail both the format and the contents of the proposed activity. In Sect. 5 we give details on the organization of the event and on data collected via the adopted platforms. Finally. in Sect. 6 we address some conclusions.

2 The Platform

The project was developed and hosted on the Smart O.C.A. platform [3], a web application to create games inspired by the "Snake and Ladders" game, developed by the Edutainment Formula company in the context of a collaboration with our team. Each cell of the game board can be associated with a video quiz. Multiple participants can challenge each other in the same session.

The game platform goes well beyond traditional table games. The game designer can generate multiplayer game instances in form of web and mobile apps that can be accesses via Internet. The graphical layout of the game board (a set of grid cells) as well as the game modalities are highly configurable. Participants of a certain game instance move in the online game board by answering quizzes presented both in video and textual form. The platform provides different game modalities: participants can either roll dices to advance in the game or move one cell at a time (as in a learning trail), they can challenge other participants when reaching special grids, jump from one cell to another (as in snakes and ladders), receive penalty or bonus, etc. The landing cell can depend on the answer to previous quizzes, allowing to build personalized learning trails.

Furthermore, a video quiz repository allows the game designer to associate quizzes with the grid cells. Quizzes are organized according to user defined categories, and can contain videos, text, images. Open questions can also be inserted, with a manual validation of the answers by the game administrator. Smart O.C.A. can be used to create a wide variety of quiz games combining the user experience typical of a multiplayer game with more standard poll apps. Indeed, participants can either play the game individually or joining a team (e.g., a class). In the latter case, for each question, answers of team members are aggregated so as to return the most voted one as team answer similarly to wooclap and kahoot. The game board of the Coding Maps instance is shown

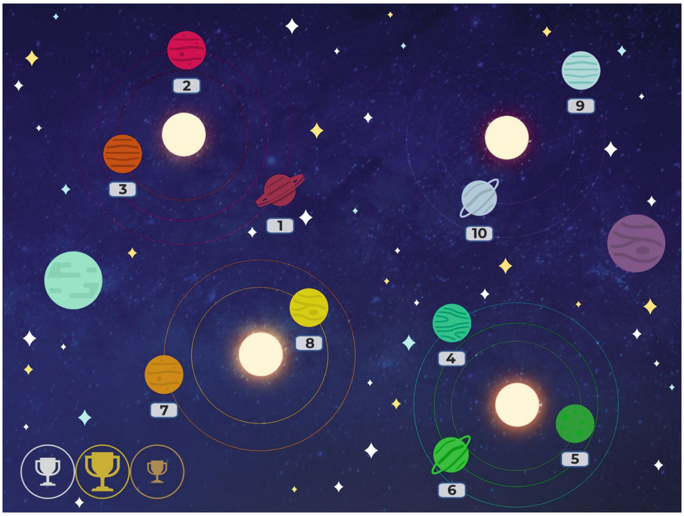


Fig. 1. The map: systems and planets

in Fig. 1. Each player (team) is identified by an avatar, and the board shows the positions of all the players in the trail (current cell) and the podium. To improve user experience, we integrated Smart O.C.A. and Genially, an online tool for producing interactive education material resulting in public web pages. In our extension, each cell of a Smart O.C.A. game instance (e.g. the 10 cells in Fig. 1) can be associated to an interactive mini game prepared in Genially. The mini game exploits interactive buttons to navigate through the different web pages of the presentation: display of the question; presentation of the answer options; presentation of the result (correct/wrong answer) with explanations in case of mistakes, as shown in the example in Fig. 2. The integration of Genially and Smart O.C.A. allowed us to associate reactive presentations with a rich graphical rendering hosted on Genially to the game instances in the multiplayer Smart O.C.A. platform. A dedicated Javascript library was developed, to provide interoperability between Smart O.C.A. and the embedded Genially web pages displayed during the game. The goal of the library is to transform the navigation in a given webpage of a Genially minigame (e.g., the page associated to a correct answer as the fourth page in Fig. 2) into a notification for submitting the answer in the Smart O.C.A. platform. This can be achieved using the following protocol:

- In every Smart O.C.A. quiz it is possible to insert the unique identifier of an external Genially website. The identifier is part of the corresponding URL address (e.g. https://view.genial.ly/60682ee2da2fe30ce2f47686 is the website of the minigame shown in Fig. 2).

Fig. 2. The four pages used to associate a mini game in Genially to a given question in Smart O.C.A.

– A special HTML element, namely a *div* tag containing a reserved word (e.g. ANDIAMO), is inserted in the source code of the Genially webpage associated to a given answer (e.g. the button with label ANDIAMO in Fig. 2).
– The smart O.C.A. platform exploits the embedding of the Genially minigame in its source code to inspect, to inject javascript and XPath code to inspect the webpage source code.
– If a *div* element with the reserved word is detected, then the corresponding answer is submitted (for the considered player or team member) to the Smart O.C.A. platform via a javascript function defined the source of the platform.

The javascript function used to bridge Genially and Smart O.C.A. is shown in Fig. 3 and works as follows. We first define an XPath expression for searching an instance of a div tag of class genially-container in the body of the Genially page currently loaded. The document is than inspected and all keyword associated to the considered tag are extracted by evaluating the XPath expression. A click event listener is the associated to the selected div tags. The listener is in charge of submitting the selected answer to the game platform. We remark the importance of dynamically loading and extending (adding parser and listener) the HTML code of the Genially mini game via HTML embedding. Angular vulnerability checks need to be disabled in order to implement the above described protocol.

Decoupling the quiz creation in Genially from the game design phase in Smart O.C.A. turned out to be quite effective for improving productivity in the design phase. Indeed, we were able to work in parallel on different quizzes and/or on modifications of the game structure.

```
findAnswerDiv(){
  var path1 = "//div[contains(@class'genially-container']
                //div[. = '"
  var path2 = "']";
  var i=0;
  for(i=0;i<this.answers.length;++i)  {
    var answer = this.answers[i].Answer;
    console.log("answer:"+answer);
    answer = answer.concat(path2);
    var xpath = path1.concat(answer);
    var result = document.evaluate(xpath,document,null,
        XPathResult.ORDERED_NODE_SNAPSHOT_TYPE, null);
    var node = result.snapshotItem(0);
    if(node==null)  {
      console.log("break;");
      break;
    }
  }
  if(i<this.answers.length) {
    console.log("timeout;");
    setTimeout(() => {this.findAnswerDiv();},500);
    return;
  }

  for(let i=0;i<this.answers.length;++i)  {
    var answer = this.answers[i].Answer;
    answer = answer.concat(path2);
    console.log(answer);
    var xpath = path1.concat(answer);
    var result = document.evaluate(xpath,document,null,
        XPathResult.ORDERED_NODE_SNAPSHOT_TYPE, null);
    var node = result.snapshotItem(0);
    if(node==null)  {
      setTimeout(() => {this.findAnswerDiv},500);
      break;
    }
    else{
      var divs=document.getElementsByTagName("div");
      console.log(node.textContent);
      for(let j=0;j<divs.length;++j)  {
        if(divs[j].innerText == node.textContent) {
          divs[j].addEventListener("click",this.
            sendGeniallyAnswer.bind(this,this.answers[i]));
          break;
        }
      }
    }
  }
}
```

Fig. 3. Javascript function to bridge Genially and Smart O.C.A.

3 The Concept

The concept has been carefully designed, devoting specific attention to gender issues: we looked for a topic that could be equally attractive for both genders. The devised topic is a journey into space, towards a mysterious planet. In this journey, the astronauts rely on a map that requires computational thinking and coding skills to be interpreted: the map should be read as a computer would read it. Thus, the map theme is intrinsic in the game. The journey consists of 10 planets to be explored, and each planet contains a question. The structure of each question is:

- Where we are,
- Which planets can be seen from the current position,
- What the map says to do: in which direction/towards which planet to proceed.

Options typically refer to possible next planets to visit (or directions). Each question has from 2 to 4 possible alternative answers.

Players navigate the map in the game board (Fig. 1) when launching dices and then land on the current planet (numbered 1 to 10 in Fig. 1) to answer a given question. The Genially minigame (see e.g. Fig. 2) is opened in order to let players navigate in the different pages. The question is formulated then from the perspective of the player (see third page in Fig. 2) after landing on the current planet.

The questions proposed during the game are formulated in such a way to interpret the map as a machine. Indeed everytime we land on a planet, the question provides instructions for the next mission that can be acquired via a correct answer.

The idea of considering a set of worlds (the map), an accessibility relation between worlds (what astronauts see after landing), and logic statements associated to each world is strictly related to non standard logic languages like modal logic [2,4,10]. The language of (propositional) modal logic consists of a set of propositional variables, a set of classical connectives, and the modal operators $\Box$ (necessarily) and $\Diamond$ (possibly) such that $\Diamond A = \neg\Box\neg A$, i.e., (possibly A if an only if not necessarily not A). A Kripke frame is a pair $\langle W, R\rangle$, where W is a (possibly empty) set of worlds, and R is the accessibility binary relation on W. The Kripke semantics of modal formulas is based on a labeling L that associates a set of truth propositional variables to each world (the variables that are true in that world). The satisfiability relation $\vdash$ is such that for all $w \in W$, variable p and formulas A and B: $w \vdash p$ if $p \in L(w)$, $w \vdash A \wedge B$ if $w \vdash A$ and $w \vdash B$, $w \vdash \neg A$ if $w \nvdash A$, $w \vdash \Box A$ if $u \vdash A$ for all u such that wRu and $w \vdash \Diamond A$ if $u \vdash A$ for some u such that wRu.

In other words propositional formulas are evaluated in the current world, whereas in order to evaluate modal formulas it is necessary to navigate to other accessible world using the R relation. We used this idea to formulate questions combining standard logic connectives with modal operators to refer to accessible or not accessibile world starting from the planet we just landed.

4 Planets and Systems

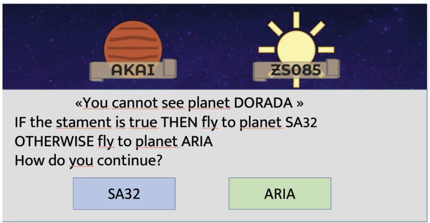
The content of the journey is organized around four planetary systems: logic, control flow, variables, input/output. Each system contains two or three planets, each with a corresponding closed-ended questions. The map of the systems is shown in Fig. 1. In what follows we present the systems, the planets, and detail the questions.

4.1 Logic

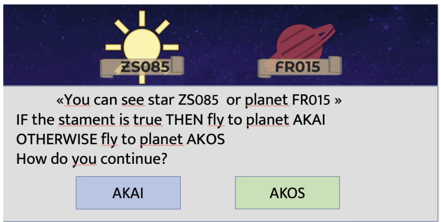
Logic is the first system to explore since it is the first step to understand the way a computer works and it has a strong correlation with natural language. Thus, it is the natural transition topic from "human thinking" to "computer thinking".

The logic system is composed by three planets, the corresponding questions are shown in Fig. 4. Question 1 is centered around negation, while Question 2 around disjunction, and Question 3 introduces (existential) quantifiers.

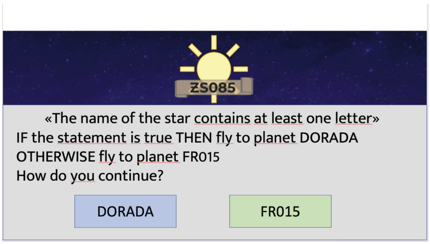
If we consider the metaphor of modal logic, in these questions players have to evaluate combinations of formulas involving modal operators to refer to visible planets (e.g. cannot see planet Dorada can be expressed as $\neg\Diamond Dorada$, i.e., there are no worlds accessible from the current planet with name Dorada, etc.). Clearly we avoided to introduce modal operators and instead adopted a graphical representation of the accessibility relation (the view of the astronaut from the spaceship).



(a) Question 1 - answer: SA32



(b) Question 2 - answer: AKAI



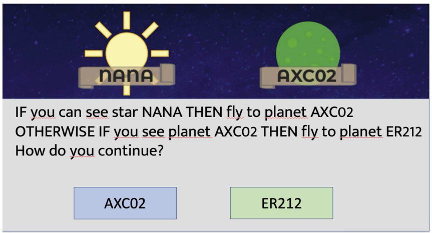
(c) Question 3 - answer: DORADA

Fig. 4. Questions for planets in the Logic system

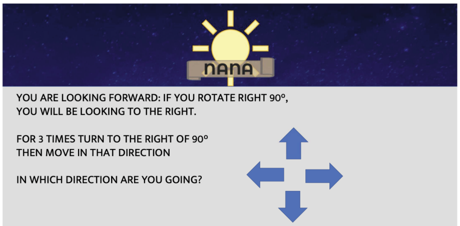
4.2 Control Flow

The control flow system is composed by three planets as well, the corresponding questions are shown in Fig. 5. In this system we get into computation thinking core concepts, actually conditionals and loops. Question 4 is about conditionals (if-then-else), while Question 5 about for loops and Question 6 about repeat loops.

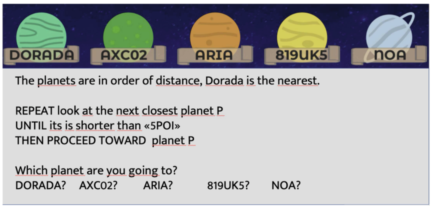
These concepts were used to implicitly present the concept of an algorithm to the students, in a simple enough way for them to understand. With the quizzes being atomic in nature, these first two groups of questions take care of breaking down problems and then solving them using the basics of computer science.



(a) Question 4 - answer: AXCO2



(b) Question 5 - answer: $\Leftarrow$



(c) Question 6 - answer: ARIA

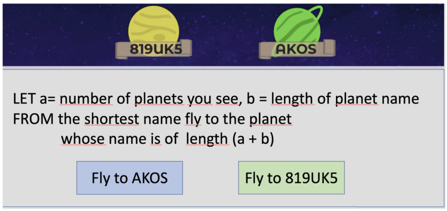
Fig. 5. Questions for planets in the Control Flow system

4.3 Variables

To give a simple layer of abstraction and the idea of a system, the third system introduces the concept of memory, implemented using variables. The system is composed by two planets, the corresponding questions are shown in Fig. 6. Both questions use variables to formulate more complex statement on basic constructs such as repeat loops. We also introduce elements derived from orienteering activities by considering directions and rotations when selecting the next destination.

4.4 Input/Output

A I/O interface is also playfully introduced, where the students must give answers to questions that comes from a different in-game entity. Even though this interaction is only simulated, it's enough to give the message that systems can be open,

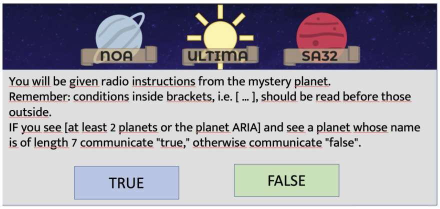


(a) Question 7 - answer: 819UK5

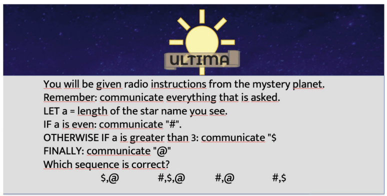
(b) Question 8 answer: ⇓

Fig. 6. Questions for planets in the Variable system

and a flow of information can go inwards and outwards. The last system is thus the Input/output system, and it is composed by two planets as well. Figure 7 contains the corresponding questions. Both questions are based on the idea of interpreting messages coming from outer worlds so as to reply with (the correct) sequences of symbols. Note that the last quizzes of the game utilize the same concepts introduced at the beginning, thus resulting in questions of incremental difficulty. This allows to give the students an opportunity to apply the knowledge they just acquired, especially if the provided wrong answers to previous questions (and therefore the correct answers were presented with explanations).



(a) Question 9 - answer: FALSE



(b) Question 10 - answer: #,@

Fig. 7. Questions for planets in the Input/Output system

5 Coding Maps in Action: The Digilab at the Science Festival

The Coding Maps project was accepted as a digiLab in the program for schools of the Genoa Science Festival. Several computer science students entered our team as tutors to conduct online the lab with the registered classes. In total 370 online participants took part in the activity in the different time slots in which it was offered. The project required a lot of efforts and allowed the entire team (both students and teachers) to improve their digital and soft skills. More specifically, designing and conducting the laboratory during the Science Festival allowed the team members to experiment a non-standard combination of technologies for distance learning, online games, and polls with more traditional computer science orientation approaches. Before exploring a galaxy, the tutor logged into the game platform and provided a brief presentation of the main concepts behind the galaxy topics. In each turn participants belong to the same School class and play as a single team. For each question, the team discussed the proposed problem and provide an aggregate answer to the tutor. This format has also been adopted for competitions among different teams each one composed by several members.

5.1 Feedback and Results

In total, the digiLab had 370 online participants, corresponding to 16 classes (12 middle school, 2 lower high school, and 2 last year of primary school). A summary of the results obtained with data collected during the activity is shown in Table 1. Some questions related to control flow, variables and I/O turned out to be more difficult than basic concepts of logic despite not all participants were acquainted with the semantics of Boolean connectives. The most difficult question resulted, as expected, to be the last one, since many participants did not realized that the second `if` was inside an `otherwise` (i.e., it was an `else-if`) and thus selected as answer the sequence `#,$,@` rather than `#,@`. Post-activity feedback was collected on satisfaction, entertainment, engagement, perceived effectiveness. The feedback was mediated by teachers, since instructors completed a post-activity questionnaire. The feedback was highly positive with respect to all the dimensions. We provided material and additional questions after the lab activities in order for instructors and participants to organize other activities in their classes. Specifically, the opportunity to repeat the learning activity autonomously, making the questions are available on Genially[1], was greatly appreciated by the teachers.

Table 1. Percentages of correct individual answers for each question

System	Logic			Control Flow		
Question (alternatives)	Q1 (2)	Q2 (2)	Q3 (2)	Q4 (2)	Q5 (4)	Q6 (4)
Perc. of correct answers	72.5%	69.2%	86.5%	78.8%	40.4%	51.9%

System	Variables		Input-Output	
Question (alternatives)	Q7 (4)	Q8 (4)	Q9 (2)	Q10 (4)
Perc. of correct answers	73%	51.9%	96%	32.7%

6 Conclusions

In this paper we have described the Coding Map project, and the corresponding digiLab at the Genoa Science Festival, resulting in a non-standard combination

[1] https://view.genial.ly/6354d9552e448300124e93b3/presentation-coding-maps.

of technologies for distance learning, online games, and polls with more traditional computer science orientation approaches based on logic and computational thinking. The development of the project and the conduction of the digiLab allowed the entire set of involved actors (both tutors, students and teachers) to improve their digital and soft skills. Thanks to this project, several computer science students got interested in principles and tools used in computer science education and several other projects aimed at exploring digital technologies (e.g., AR and XR) emerged as possible interesting future directions for continuing our work.

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New Educational Scenarios in the Framework of Blended Learning

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Abstract. This work introduces readers to the use of BL in educational institutions. A theoretical framework will be built, in which the latest developments of BL in higher education environments are reported, with an examination of the digital services that are made available to teachers and students during the pandemic. The main purpose is to present a critical reflection on the possibilities that BL has offered during the COVID-19 pandemic and what it will be able to offer in the post-pandemic age. The crucial aspects of digital culture in the contemporary world of education and training are highlighted, outlining an essential theoretical path that emphasizes the substantial ad-vantages and tools offered by technology. A definition of BL is provided below, based on the definitions given by authors who have received the most international credit for their work. The study is presented as an exploratory investigation of the blended model for higher education, and is articulated with various references to the most recent strategies implemented by educational institutions. The main reference is the aforementioned Horizon 2021 Report, published by EDUCAUSE. Based on the results, we can gauge the willingness of educational institutions to invest in the design of new educational paths that use a blended methodology, to provide concrete support to teachers to fill in any gaps with respect to their digital skills. The reflection is supported by concrete examples that demonstrate some good practices that were followed at international universities, and provides as an outcome, an updated list of best practices using which it is possible to stimulate a constructive debate, innovative study, and re-search projections for the global scientific community.

Keywords: Blended Learning · Learning environments · New scenarios

1 Introduction

Learning itself is a very complex process that accompanies the entire life of individuals [1]. In recent decades, educational technology and the emergence of digital culture have assumed an increasingly important role in the learning process. The ultimate goal of the use and implementation of innovative methodologies is to overcome the problems associated with the learning process, facilitate it and promote its interest; in fact, online learning has become so common and popular because of its great potential: being able

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to provide flexible access to educational content at any time, in any place and by any means.

The health emergency from Covid-19 has prompted more use of innovative technologies for online education, increasing interest in Blended Learning (BL). The concept of BL is by no means new but has its roots in the early 2000s, coinciding with the advent of e-learning and telematic networks. Although it is not a recent methodology, attention to BL in recent years has increased significantly; in fact, there is no doubt that BL is developing more and more and is inevitably changing the classic teaching method carried out in the classroom. As reported by the 2021 Horizon report "2021 EDUCAUSE Horizon Report, Teaching and Learning Edition," the blended model has been defined as one of the macro trends that will shape the future of postsecondary teaching and learning. The rapid shift of institutions to blended or hybrid models, the widespread adoption of digital technologies for course redesign, and pedagogical transformations have posed significant challenges for both students and academic communities [2].

2 Digital Culture and New Learning Environments

According to geneticist Cavalli-Sforza [3], culture can be understood as "the result of many changes that brought with them information and knowledge, which were learned by individuals put in a position to adapt to change." Since the 20th century, a new concept of culture, digital culture, has emerged, developing since the 1960s in the United States and presenting itself as something different from what has occurred in the past, for example with print or broadcast culture. Digital culture can be understood as the way in which culture is shaped by the introduction and use of digital technologies, which as Fini [4] states “shape more interconnected, collaborative and participatory forms of culture.” It follows, then, that digital technologies are a product of digital culture itself and foster its development [5].

The same academics state that digital culture “is not only breathed in the presence of digital artifacts but is the result of the organization of knowledge and acting that structure and are structured by digital technologies. The behaviors or ways of thinking of humans today reflect digital culture even when they are not physically in contact with digital artifacts.”

According to Luzi and D’amore [6], digital culture has developed precisely because of new innovative technologies and has three main elements, which are: participation, digitization and reuse of information. Of particular relevance is the concept of digitization, which has profoundly changed the way learning is done, making it more accessible and usable. Digital culture, according to Greco and Caria [7], requires a constant implementation of digital skills at multiple levels, oriented both to tool management and content management.

In light of the above, it is possible to say that since the 20th and 21st centuries, digital culture and new technologies and thus the whole process of digitization that goes with it have profoundly changed the field of education and training, integrating and supporting it through multiple remote resources, with particular regard to the use of the Web [8]. The term ICT Information and Communications Technology refers to all technological processes and tools that are used to produce and improve knowledge and learning tools.

The use of ICT to support educational processes is growing greatly and steadily. The goal is to ensure learning from a lifelong perspective, that is, throughout life, beyond the spatial-temporal limitations imposed by traditional educational systems. And it is precisely in this perspective that the concept of e-learning, developed since the 1990s with the advent of telematic networks, fits perfectly.

The term e-learning refers to "a set of methodologies that make use of the Internet and multimedia technologies to provide distance learning experiences" [9]. For Elliott Masie [10], e-learning is "the use of technology to design, distribute, select, administer, support, and disseminate training." The lowercase e-, placed before the term learning, stands for "electronic," but for Masie himself it can be understood as short for "experience." The ultimate goal of any e-learning system is to convey content. The tools and methods by which e-learning can be organized are many; this entails a variety of flexible solutions by placing the subject at the center of an articulated and extended educational offering, making it possible for the learner to play a dynamic role in learning; the focus is thus on the user.

With the advent of new technologies, the learning environments in which the educational process is enacted also change. In fact, today's learning environments are very different from the traditional ones: as Rivoltella and Rossi [5] state, "when learning takes place by operating in a logical (and dynamic) online space generated by a digital system, we speak of a networked learning environment, understood as a space defined by the system of relationships and tools that takes shape online with the aim of supporting learning through an educational process in which it is possible to recognize a cultural and social dimension."

The same authors, in the text "Technologies for Education" [5], make a categorization of environments from the contributions of digital technologies and the following dimensions:

- The nature of the environment, integrated into blended, transmedial or augmented reality processes;
- The immersiveness of the environment;
- The timing of the teaching action, bearing in mind that the environment may be able to configure synchronous and/or asynchronous settings.

These three dimensions should not be considered as something separate but intersect in order to co-construct educational processes from a transmediality and multimodality perspective.

The above categorization of environments can be explicated as follows [5]:

- Environments characterized by presence, with the use of non-immersive media tools: in this case, there is the possibility of having only synchronous situations with the use of classrooms having different devices (such as interactive whiteboards or video projectors);
- Environments characterized by the presence, with the use of immervised tools such as the setting up of environments/worlds in which to situate teaching: in this case, there is the possibility of having both synchronous situations (through the use of VR or AR Headsets in situations where synchronous negotiation and collaboration with

the subjects present in the classroom is possible) and asynchronous situations (with the use of AR Headsets in site with scheduled instruction);
- Online environments with non-immersive media tools: in which case there is the possibility of having both synchronous (with the use of video conferencing software, chat or shared documents) and asynchronous situations (through the use of forums, shared documents and collaborative writing software);
- Online environments with immervised media tools: again, there is the possibility of having both synchronous situations (with the use of VR or AR viewers in situations where synchronous online negotiation and collaboration is possible) and asynchronous situations (with the use of AR headsets at site with scheduled online instruction).

The importance of place also expands in the contexts of university education where the environment in which learning progresses is very often diffuse and open (on site and online), unconstrained by boundaries, and can be viewed as the system in which elements of physical and/or virtual architecture and fundamentals of pedagogy and didactics are interwoven. Professionals involved in designing educational interventions are called upon to collaborate with the environment, and thus to interact and create a constructive dialogue with it. Rivoltella and Rossi [5] point out that “the continuous development of technologies in the various interweavings between presence and online, and the incidence they can have in helping to construct the characteristics of the setting in relation to the training objectives, impose reflection from a design perspective.”

It is important to emphasize that when discussing the design of learning environments, it is necessary to pause and analyze the combination of “teaching process” and “characteristics of the environment.” In this sense, scholars Rivoltella and Rossi [5] speak of isomorphism: an environment that is isomorphic to an instructional process presents tools and characteristics that are perfectly compatible with it, as it “not only makes instructional actions possible but suggests them. In other words, it is structuring.” If this isomorphism is lacking, there may be difficulties in achieving desired levels of effectiveness.

Speaking of learning environments, it is crucial to analyze the so-called Ubiquitous Learning (U-Learning). Ubiquitous learning is based on Ubiquitous Computing Technology which uses various electronic devices allowing learners to learn anywhere, anytime [11]. As Pierpaolo Limone [12] states, such a model is “inherent to the actions of daily life, it ’follows’ the learner even outdoors, resulting in enhanced and always present and accessible information resources and spaces for sharing.” Ubiquitous learning environments are very different from traditional environments in that there is a very high level of integration between mobility and the environment itself: in fact, the learner is free to move how, where and when he/she wants as the system will always be able to dynamically support the learning process [13]. Thanks to this type of learning environment, the whole process of communication and information sharing becomes more natural and immediate, which has positive repercussions in terms of outcames: U-Learning gives the opportunity to learn while respecting not only one’s own pace but, above all, one’s own abilities. A mobile type of learning allows knowledge to be available at all times, but also the forms by which it is structured.

3 Blended Learning: Theoretical Framework

In light of the above, it can be said that the use of e-learning and new learning environments have produced a shift in perspective and paradigm. This is where Blended Learning, a not-new construct that has its roots since the 2000s, fits in. Although it may seem like a very intuitive concept, its application and definition is actually very complex.

According to Ossiannilsson [14], BL is a methodology that is strongly influenced by context, which is why its definition has changed over time and will continue to take new directions; in fact, for some researchers, the concept of BL seems to be redundant and no longer as relevant as it once was, while for others, it is an approach that is yet to be explored and relevant in terms of its value in educational research. The term BL connotes various possible combinations of instruction, information, and interaction that can occur in the classroom and online context.

Generally, in the literature when addressing the topic of BL, it is usual to use the definitions of Graham [15] and Garrison and Kanuka [16]. As reported by scholar Hrastinski [17], Graham [15] defines BL as a learning system that combines face-to-face and computer-mediated learning. The scholar further states that BL actually refers to traditions, practices, and norms that have long been familiar to many educators [14]. Garrison and Kanuka [16], on the other hand, state that BL is given by the thoughtful integration of face-to-face learning experiences with online learning experiences.

According to the most recent definitions, Hrastinski [17] defines BL as an approach that combines the latest web-based methodologies and technologies, new instructional technologies, and different pedagogical models; Stepanova [18], on the other hand, defines it as a promising learning system that combines the best aspects and advantages of the traditional classroom and interactive online learning to create accessible and motivating courses for modern students.

BL is a student-centered methodology. This means that the student is not merely a passive user of knowledge but has an active and dynamic role in the entire learning process. This is because BL includes not only the physical presence of students and teachers but also control, on the part of the students, of the time, place, environment, path, and pace at which learning is enacted; blended is a strategy that helps teachers accomplish what they strive to do every day: understand and enable each student to achieve the highest levels of educational mastery [14]. Indeed, there is a shift from a linear model of knowledge, characterized by the here-and-now time constraint, to a networked model. In addition, through these methodologies, the processes of formal, informal and social learning, once conceived as something separate, are increasingly harmonizing.

BL, like any methodology, has several advantages and disadvantages. Starting with what are the strengths, we recall first and foremost the possibility, on the part of students, to adapt and individualize their learning experiences; in fact, students have the opportunity to work and learn according to their needs, time and pace. In fact, the learning process in a blended environment is personalized, allowing students to reach their full potential. Thus, doing so not only accommodates the individual needs of all learners but also significantly increases their creative thinking [14]. The two key words in this view are cooperation and collaboration, which means being actively involved in the educational process. In fact, learning is carried out from a perspective of confrontation and collaboration between student and user, making use of learning by doing and developing cognitive processes such as memorization, comprehension and problem solving. Several studies have shown that blended learning is particularly beneficial in reducing students' anxiety in communication, improving peer and student-teacher interaction, increasing students' motivation for independent learning, facilitating flexibility and curiosity in learning, and enabling students to learn more actively [19].

In addition, there is an increase in the quality of training by providing immediate feedback regarding the quality and effectiveness of learning. The relationship between learner and teacher finds in the feedback the most important moment on both quantitative and qualitative levels, helping the subject to adjust and adapt his behavior in view of the objectives to be achieved and the teacher to take information on the state of understanding, provide concrete answers following specific requests from the learner, helping him to overcome doubts and errors [9].

Another strength of using BL concerns the possibility of using different methodologies such as Cooperative Learning, Peer to Peer strategies, Gamification, Game-Based Learning and Project-Based Learning. In addition, as Andrews [20] states, learners prefer a blended approach as they are able to have more time for processing and reflecting on course content; all of which, therefore, positively affects learners' meta-cognitive skills.

Since BL is a methodology that makes use of new technologies and different platforms, this can be a point of form, yes, but also a point of weakness. This is because, if the Moodle platform in which this methodology is implemented is not well organized and designed, it will inevitably have negative repercussions on the learning process and thus on the expected outcames. The same applies to the devices used: the tools must be reliable, easy to use-in terms of accessibility and usability-and continuously updated in order to have significant effects on the learning experience.

Another significant obstacle relates to the inadequate Digital Literacy digital literacy of students and teachers, linked to the lack of knowledge of technological and digital devices. Students' digital illiteracy, in fact, causes a delay in interacting with their instructors and peers, leading to definite procrastination and setbacks in their performance [21]. In fact, there is a tendency to assume that the instrumental use of digital technologies for teaching and learning produces digital competence per se; the result in reality is that even new generations of teachers and students are unprepared in terms of digital competence [5]. Thus, it is important to emphasize how a good level of digital literacy and computer skills are essential for Blended Learning.

The concept of BL should not be confused with Technology Augmented Learning, which can be understood as the use of technologies, including online technologies, in the classroom. Another necessary distinction concerns the hybrid approach. Indeed, the terms "blended" and "hybrid" are often used interchangeably in the literature, and there is no widely accepted precise definition [22]. In fact, these are two very different concepts. Hybrid learning is an educational model in which while some students attend inperson classes, others have the opportunity to attend virtually. This brings with it a not inconsiderable advantage in that teachers are able to conduct classes with both classroom and distance learners through the use of software for videoconferencing. Trentin [23] defines hybrid spaces as "dynamic spaces created by the constant movement of people with mobile devices perpetually connected to the

Internet and/or cellular network."

Hybrid environments are defined by three key dimensions that are [24]:

- the physical dimension (the space one is physically in at the moment);
- the digital dimension (everything that through technological devices is introduced into the
- physical space: virtual environments, remote labs, digital informational and factual resources, etc.);
- the dimension of social interaction.

4 A New Blended Model: Future Scenarios

As is now well known, due to the Covid-19 pandemic, about 90 percent of students have been forced to leave their university and school desks. Institutions have tried to cope with the pandemic by seeking quick and alternative solutions, investing in distance learning solutions through the use of various online platforms.

It is possible to say that the pandemic has revolutionized the world of education, pushing and accelerating a paradigm shift toward hybrid and blended models. In fact, the changes and strategies put in place on an emergent basis cannot be considered a parenthesis in itself but the whole thing has profoundly changed the world of Higher Education.

As reported by the "2021 EDUCAUSE Horizon Report, Teaching and Learning Edition" [25] as the adoption of blended or hybrid learning models accelerated, the adoption of new learning technologies and tools that support and even model the implementation of such models also increased. Post pandemic, institutions around the world began to realize that there was a need to move beyond emergently delivered distance learning to a flexible and quality online learning model by increasing the use of blended/hybrid learning modes/models.

Taking the area of blended learning into consideration, the most recent studies in the literature have highlighted the emergence of a "new" blended model. In this new combination of blended learning, lacking the physical environment and the ability to conduct face-to-face classes, all interactions are conducted online and are mediated by a device: there is, in fact, only alternation and a "blend" between synchronous and asynchronous through the support and use of video conferencing tools [26]. The alternation between face-to-face and online, a characteristic feature of the blended model, are thus absent. This "new" blended model has aroused particular interest in Faculty Development and Higher Education; this is because the possibility of having full online training synchronous and/or asynchronous-allows the trainee to personalize his or her learning process. This is because, as Alvarez Jr [27] states, BL has the potential to bring flexibility to teaching and to learning, is able to promote independence, accessibility and increase opportunities for networked learning.

In light of the above, it is necessary to invest in the redesign of courses using blended models and to provide the right support-technical and otherwise-to both learners and teachers.

In this sense, in the international scenario, there are many universities and campuses that have responded promptly to the major difficulties encountered by faculty and students in using these new models and methodologies. Such is the case of Penn State University-Penn State University based in the small town of State College-which has decided to launch a program of Tech TAs (Technology Teaching Assistants), whose purpose is to provide faculty with real-time support so that faculty can "focus on the learning experience of their students." These tech TAs, in fact, provide not only precourse assistance but also during each distance learning class so that they can provide the correct assistance should technical problems arise. This program has been implemented at all 23 Penn State campuses (https://techtutors.psu.edu/tech-ta-forms/). Santa Clara University, on the other hand-a private U.S.-based Jesuit university in Santa Clara, Silicon Valley-has developed a course for students called LEVL Up (Learning and Engaging in Virtual Learning) that “encourages students to adapt to the reality that their learning and most extracurricular activities will be online, while providing resources to ensure their virtual success.” And again, North Carolina State University-a public U.S. university based in Raleigh, North Carolina-has created a design framework with “flipped” and self-regulated learning cycles based on cognitive, metacognitive and motivational theories. This framework was applied in the redesign of four undergraduate courses (economics, biochemistry, computer science, and mathematics) that were implemented in fall 2019 and translated into “bicrons” (asynchronous and synchronous) during the pandemic.

5 New Blended Models: The Scenario of the University of Foggia

In the Italian context, even small universities, such as the University of Foggia, have readily responded not only to the pandemic but also to the period immediately following it. Before analyzing the changes implemented by the University of Foggia, it is useful to state that it was one of the first Italian universities to adopt a type of blended teaching delivery. In fact, as of a.y. 2015/2016 there were 36 blended teaching courses delivered within the university’s e-learning platform. After Covid-19, there were 1219 active teaching courses in blended mode. The response of the University of Foggia, as Perrella and Borrelli [28] state, has been “of quality, characterized by resilience and commitment to best practices, structuring each course ad hoc with 7-day-a-week support.”

The University of Foggia, however, in addition to the blended model put in place over the years, the synchronous and asynchronous mode of teaching delivery, successfully tested in A.Y. 2019/2020, has introduced, starting the following A.Y. 2020/2021, a new mode of teaching delivery, defined as “dual”, with lectures delivered simultaneously in presence and at a distance, in line with the implementation of a gradual recovery plan. The model toward which the University of Foggia is moving increasingly sees the use of hybrid methodologies. As Toto and Limone [29] state, “The most significant change, however, lies not in process modifications, but in a different representation of the roles of the student and the teacher. In the Unifg model, students are at the center of a system of hybrid services, partly digital and partly face-to-face, which allow them to be active, that is, stimulated in their agencies and supported in that capacity that makes them the protagonists of the process of knowledge construction through the stimuli provided by the university.”

This necessitated, on the one hand, timely technological upgrades to existing facilities and, on the other hand, further training of faculty: distance learning requires different professionalism, inspired by changing learning models and adaptable to contextual needs [24]. The prompt response on the part of the University of Foggia was consequential to the realization that the educational model toward which it is tending sees a hybridization between digital practices and in-presence teaching, in a mutually influential relationship. The pandemic experience, in fact, has not debased traditional didactics, but, rather, has led to the emergence of new needs, which impose a revision or, at least, a reorganization of the tools and resources hitherto in use [13].

Taking on paradigmatic value is the considerable increase in participation in extracurricular activities, such as seminars, conferences, etc., produced by the opportunity to remotely attend in-person events, in order to cope, today, with the risk of contagion and, tomorrow, with the shortage of space. Predictably, this will lead, with increasing frequency, to a preference for "dual" mode delivery.

Indeed, educational success lies not in the intrinsic value of technology or innovative methodologies, but in how both can be an effective means of bridging the environmental gap [30]. In the future, therefore, it will be necessary to reconsider the traditional, at times constrained, choice in favor of completely de visu teaching and opt for hybrid and blended models that can meet the needs of flexibility, accessibility and ubiquitousness of learning: not a simple mixture of face-to-face and distance learning, but a model in which the transfer of skills and knowledge takes place between peers (teacher-teacher, learner-learner) and non-peers, always with the support of digital tools [31].

6 Conclusion

In light of the above, it is possible to say that Blended Learning has become a traditional to learning in higher education; BL is becoming more and more common, and this has entailed-and is still entailing-a mindset and paradigm shift in the pedagogical context. Teachers, who use this approach, draw on a mix of digital technologies and face-to-face approaches with the goal of improving their students' learning outcomes [14]; this is because BL exposes students to an authentic, active and flexible learning experience [21]. Moreover, although many faculty and students feel the need to return to the classroom, many others are inclined to retain the flexibility offered by online courses and Blended Learning. Especially, the Faculty Development and Higher Education fields seem to be interested in this "new" BL model. As Luzi and D'amore [6] state, "the new contexts and communicative modes are united by intertextuality, inter- activity, multimedia and digitization, all innovative phenomena that have brought an unprecedented revolution."

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Technology and Digital

Brain Wave, Heart Rate, and Facial Expression Relationship Validation During Programming Learning Comprehension Study

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Abstract. The impact of COVID-19 is attracting continued attention for online classes. Among the various online class formats, on-demand classes are better adapted to various lifestyles. However, on-demand teaching uses pre-prepared educational content and cannot be tailored to an individual's level of comprehension. In order to address this issue, it is important that the system understands the student's learning state. Many studies have been conducted to estimate learning state by measuring brain waves. However, it is unrealistic for students to wear an electroencephalogram on a regular basis while the act of learning is in progress. This study measures biometric information during programming learning and predicts brain waves using heart rate (HR) and facial expression. Specifically, multiple regression analysis was performed with electroencephalography (EEG) as the objective variable while HR and 10 facial expressions served as explanatory variables. Furthermore, to avoid overfitting, a combination of explanatory variables that minimized the root-mean-square error (RMSE) was determined using the Leave-One-Out Cross-Validation method.

Keywords: Programming learning · Learning state · Brain wave · Heart rate · Facial expression analysis

1 Introduction

In recent years, several fully online universities and other institutions have emerged to offer a learning platform that accommodates a wide variety of lifestyles. In addition, after COVID-19, online classes and hybrid classes have rapidly spread as a new form of learning primarily out of necessity. Furthermore, flipped classrooms wherein students access learning material prior to its discussion in class are attracting attention even in the teaching method of traditional universities. The rationale

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behind this teaching concept is that self-study before face-to-face classes plays an important role in the enhancement of learning comprehension. Thus, demand for self-study is increasing.

Conventional self-study systems use only pre-prepared learning content which are not capable of responding to the individual learning status of each student. Although remote video chat is a substitute for traditional face-to-face learning in a physical classroom, individualized real-time conversations with learners who have varying schedules require too much of the instructor's time. Meanwhile, for on-demand classes that do not offer real-time teaching instruction, it is desirable to grasp the learning status of individual learners and provide learning content most suitable for each one.

There have been many studies on electroencephalography (EEG) [1,2] as a means to measure learning [3]. In addition, there has been research on estimating task difficulty using EEG [4]. Another study showed that human brain activity level can be measured by evaluating β/α values [5]. Many studies have also been conducted on other biometric information to investigate learning. These include eye tracking [6], monitoring heart rate variability [7], and measuring concentration through facial expression analysis during learning [8]. We also conducted a follow-up experiment and again confirmed that β/α values were higher when subjects tackled difficult tasks [9]. In addition, a related research project on self-study systems that use biometric information such as EEG to understand learning state is currently underway [10]. This series of studies focused on α and β waves experimentally verified a method for learners to estimate the difficulty level of a task. Based on these results, this study also proposes a system for estimating learning state [11].

However, it is not realistic to have students wear EEG devices in promoting self-study systems that monitor various learning situations to provide optimal learning content for each individual.

Therefore, we measured the relationship between brain wave, heart rate, and facial expression while subjects performed tasks of different difficulty levels (easy, medium, and difficult) with the aim of finding alternative biological information to brain wave for estimating learning state [12]. Specifically, we performed multiple regression analysis with brain wave as the objective variable while heart rate and 10 facial expressions served as explanatory variables to obtain regression equations.

This study addresses overfitting from the previously conducted study [12], and instead of using all explanatory variables, aims to find a combination such that the root-mean-square error (RMSE) is smallest.

2 Previous Work

2.1 Application of Brain Wave to Learning

In the fields of psychology and brain science, it has been empirically known that electroencephalogram waveforms together with related events can be used as a mental state index [1]. In addition, research has been conducted to observe human mental states using α and β waves obtained by applying the discrete Fourier transform to brain waves [2].

Previous studies [3] focused on the fact that β waves are highly related to thinking states and measured brain waves of subjects during an intelligence test in order to investigate the relationship between brain waves and intellectual tasks. Results showed that the β wave low-frequency component was dominant during the reading test, math test, and figure alignment test which meant that β waves are effective to some extent as an index for estimating thinking states.

Also, other previous studies [4,5] demonstrated the effectiveness of measuring the power spectra of α and β waves, percentage of α and β waves to total EEG, and ratio of α and β waves in order to observe the human thinking state.

2.2 Other Biometric Applications for Learning

Studies have been conducted on other biometric measurements such as eye tracking. One such previous work [6] presented state-of-the-art research consisting of six empirical studies, one theoretical paper, and two discussions regarding educational science and eye tracking.

In a previous study [7], heart rate variability (HRV) was measured during second language learning while stress was measured and fed back to participants to train them against stress. It was reported that the participants were able to control their stress.

Furthermore, previous research [8] argues that analyzing students' concentrations can enhance the learning process. Specifically, a prototype system is proposed to monitor concentration in real time based on facial expressions during learning.

2.3 Previous Work on Estimating Task Difficulty Using EEG

By using a typing practice software that can set easy and difficult tasks, this study confirmed previous studies, namely, that the more difficult the task, the higher the β/α value. In addition, the study found that the low low-β-wave/low-α-wave ratio increased when working on difficult tasks [9].

The previously conducted study proposed a method and system for estimating a student's learning state by comprehensively analyzing learning history and brain wave [10]. Additionally, an experiment was conducted with high school students wherein their learning state was assessed while learning the C and Scratch languages. Estimated results were then compared with the questionnaire results to argue the effectiveness of the proposed method [11].

3 Experiment

The study simultaneously measured multiple types of biometric information (brain waves, HR, and facial expression) when performing programming tasks with different difficulty levels (easy, medium, and difficult). Obtained data was analyzed to explain brain waves with other biological information such as HR and facial expression.

3.1 Questions to Use for the Experiment

This experiment used the Paiza Learning [13] website which provides free programming education. This website offers practice programming problems. For each problem, the number of people who have attempted it and the percentage of correct answers are displayed. Problems of three levels of difficulty (easy, medium, and difficult) were used wherein the experiment obtained 91.88%, 80.84% and 49.35% correct answers. The, respectively. Although the site can handle a variety of programming languages, Java was chosen for this experiment. The questions used in this experiment cannot be included in the pictures or text as due to handling conventions of Paiza Learning. Instead, a brief overview is given in Figs. 1, 2 and 3.

D rank question 114: Price including tax

The question calculates price including tax from two numbers entered (the first number is the consumption tax rate (%) and the second number is the price excluding tax).

Fig. 1. Summary of Question A (correct answer rates of 91.88%)

C rank question 017: High and low card game

A parent number and several child numbers are entered. The parent and child numbers are compared according to certain rules. If the parent figure is stronger it is displayed as “High”, otherwise, it is “Low”.

Fig. 2. Summary of Question B (correct answer rates of 80.84%)

B rank question 016: Where is here?

Multiple directions of movement (x- and y-directions) and distances of movement are entered; the question is to answer where on the 2D map is the final point.

Fig. 3. Summary of Question C (correct answer rates of 49.35%)

3.2 Biological Equipment Used for Experiments

Simple EEG. The study used NeuroSky Inc.’s MindWave Mobile 2 for EEG measurements. As shown in the EEG manual [14], this device detects the potential difference (voltage) between FP1 (forehead) and A1 (ear) in the international 10–20 system for EEG. The signal is finally sampled 128 Hz after correcting for possible aliasing. It is then analyzed every second to detect and correct noise artefacts as much as possible. A standard fast Fourier transform (FFT) is performed on the filtered signals to recheck for noise and artefacts in the signal frequency domain. The headset is connected to the ThinkGear Connector on the PC through Bluetooth with the ThinkGear Connector and logging application connected by TCP/IP to collect EEG data. The ThinkGear Connector is a driver that provides communication with the MindWave Mobile 2 provided by NeuroSky. The eight types of brain waves that can be acquired with this EEG are shown in Table 1, each value being a unitless 4-byte floating decimal value.

In this study, four types of α and β waves are used: low α waves, high α waves, low β waves and high β waves, in accordance with the previous study [5]. From now on, low α waves are denoted as α_l and high α waves as α_h (the same applies to β waves). In this study, based on the previously conducted research [9], five combinations of β/α including the average of low and high frequencies (β_l/α_l, β_h/α_l, β_l/α_h, β_h/α_h, $(\beta_l+\beta_h)/(\alpha_l+\alpha_h)$) were used to calculate the ratio of low and high frequencies. From now on, $(\beta_l + \beta_h)/(\alpha_l + \alpha_h)$ will be denoted as β_{l+h}/α_{l+h}.

Table 1. Types of brain waves which can be acquired

Kind	Frequency (Hz)
δ wave	0.5–2.75
θ wave	3.5–6.75
low α wave (α_l)	7.5–9.25
high α wave (α_h)	10–11.75
low β wave (β_l)	13–16.75
high β wave (β_h)	18–29.75
low γ wave	31–39.75
mid γ wave	41–49.75

Heart Rate (HR) Monitor. The study used Union Tool Corporation's "myBeat" wearable heart rate sensor WHS-1 to measure HR. WHS-1 can measure three types of biological data: heart rate, acceleration, and body surface temperature. Data was collected using a dedicated USB receiver and the accompanying dedicated software.

Facial Expression. Recording and analyzing facial expressions are necessary to perform facial expression judgments. The study used a Logitech C920n webcam for recording facial expressions. For analysis of the recorded facial expressions, CAC's mind sensor (equipped with the emotion recognition engine manufactured by Affectiva) was used. This application recognizes human faces from filmed or real-time video and can quantify emotions (anger, contempt, disgust, fear, joy, sadness, surprise, neutral, engagement, and valence). It can also quantify blinking, facial orientation, and the coordinates of facial parts. In this study, the 10 aforementioned quantified emotions are used. The emotions other than valence are represented by a number between 0 and 100 while valence is represented by a number between −100 and 100. In this case, anger, contempt, disgust, fear, sadness and surprise are considered negative emotions while joy is considered positive.

3.3 Experiment Participants

Nine Shonan Institute of Technology fourth-year students participated in the experiment. They all had four years of experience in taking programming-related classes in the Department of Information Science. Although there may be some differences, their programming skills can be considered at the same level.

3.4 Experimental Method

First, the participants wear measurement devices (electroencephalograph and heart rate monitor) that capture biometric information. A webcam for recording facial expressions is installed on the PC monitor. The distance between the PC monitor and the participant is about 1 m as in normal desktop PC work to replicate online learning. To test the equipment, biometric information is measured for approximately five minutes while the subject is sitting in a chair not doing anything. Their biometric data was then measured while they programmed questions A, B, and C, respectively. The set programming time for each was: 10 min (question A), 20 min (question B), and 30 min (question C). However, participants were not informed of these time limits ahead of the experiment. A one minute break was allowed between each question. The flow of the experiment is shown in Fig. 4.

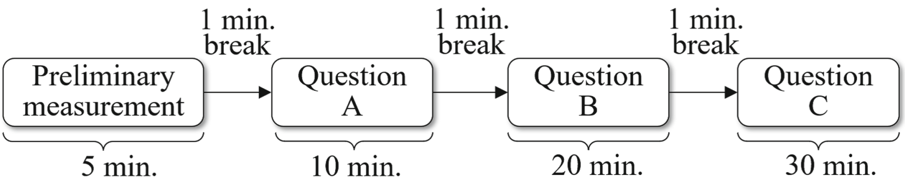

Fig. 4. Experimental flow

Table 2. Difference in average value of biometric information of participant 1

	Kind	Alias	AB	AC	BC
Brain wave	β_l/α_l	y_1	−0.0293	0.1025	0.1318
	β_h/α_l	y_2	0.0197	0.5995	0.5798
	β_l/α_h	y_3	−0.0308	0.1093	0.1401
	β_h/α_h	y_4	0.0745	0.7560	0.6815
	β_{l+h}/α_{l+h}	y_5	−0.0024	0.3946	0.3970
HR	heart rate	x_1	−1.8310	−16.4162	−14.5853
Facial expression	anger	x_2	0.0004	0.0236	0.0233
	contempt	x_3	0.0019	0.0033	0.0014
	disgust	x_4	0.0003	0.0516	0.0513
	fear	x_5	0.0000	0.0118	0.0118
	joy	x_6	−0.0614	−0.0607	0.0008
	sadness	x_7	0.0001	0.2887	0.2886
	surprise	x_8	0.0000	0.0171	0.0171
	neutral	x_9	0.0689	−0.4914	−0.5603
	engagement	x_{10}	−0.0837	−0.0014	0.0823
	valence	x_{11}	−0.0541	−0.0267	0.0273

4 Experimental Results and Analysis

4.1 Analysis of the Difference [12]

As shown in references [12], it was not possible to obtain a valid multiple regression equation with the average values of heart rate and facial expressions while participants completed each question. Therefore, this study focused on the average difference in heart rate and facial expression while participants solved each question. As a sample, the results for participant 1 are shown in Table 2. Each number in the table is the difference between the average biometric values that were measured while solving each question. For example, the values in column AB are the difference between the average biometric values while solving question A and the average biometric values while solving question B.

The objective variables were five individual β/α values. Meanwhile, the explanatory variables were heart rate, anger, contempt, disgust, fear, joy, sadness, surprise, straight face, expressiveness, and emotional valence. Multiple regression analysis was performed on these variables. In conclusion, the coefficient of determination (contribution ratio) was high for all objective variables (y_1 to y_5). The contribution ratio for each multiple regression equation are shown in Table 3. As a general rule of thumb, a useful regression equation is considered to have been obtained if the contribution ratio is greater than 0.5. Therefore, it can be said that this analysis produced useful regression equations for all the objective variables.

Table 3. Coefficient of determination (contribution rate) of multiple regression equations for objective variables (y_1 to y_5)

Objective variables	Coefficient of determination R^2 (Contribution rate)
β_l/α_l (y_1)	0.8906
β_h/α_l (y_2)	0.9186
β_l/α_h (y_3)	0.8995
β_h/α_h (y_4)	0.8575
β_{l+h}/α_{l+h} (y_5)	0.9030

Multiple regression equations with each of the five brain waves as the objective variable were obtained as shown in Eqs. (1)–(5). The regression coefficients (shown in bold) in these equations indicate that the p-values were significant at the 5% level as a result of multiple regression analysis. It can be seen that many of the explanatory variables are significant at the 5% level.

$$\begin{aligned}\hat{y}_1 = &-\mathbf{0.0074}x_1 + 0.1400x_2 + \mathbf{0.2357}x_3 - \mathbf{0.3210}x_4\\ &+\mathbf{4.4347}x_5 + \mathbf{0.2137}x_6 + 0.1805x_7 - \mathbf{0.9765}x_8\\ &+\mathbf{0.1322}x_9 - \mathbf{0.0164}x_{10} - \mathbf{0.0441}x_{11} - 0.0249\end{aligned} \tag{1}$$

$$\begin{aligned}\hat{y}_2 = &-\mathbf{0.0408}x_1 + \mathbf{2.2297}x_2 - 0.2697x_3 - \mathbf{0.5901}x_4\\ &-1.0580x_5 - 0.3072x_6 - \mathbf{0.7093}x_7 - \mathbf{2.1025}x_8\\ &-0.2420x_9 + 0.0049x_{10} + 0.0498x_{11} + 0.0237\end{aligned} \tag{2}$$

$$\begin{aligned}\hat{y}_3 = &-\mathbf{0.0117}x_1 + \mathbf{1.0896}x_2 - 0.0903x_3 + 0.1010x_4\\ &-\mathbf{1.9064}x_5 + 0.0650x_6 - 0.2159x_7 - 0.2238x_8\\ &-0.0080x_9 - \mathbf{0.0149}x_{10} - \mathbf{0.0453}x_{11} - 0.0015\end{aligned} \tag{3}$$

$$\begin{aligned}\hat{y}_4 = &-\mathbf{0.0545}x_1 + \mathbf{3.8361}x_2 - \mathbf{1.4383}x_3 - 0.5347x_4\\ &-\mathbf{9.5242}x_5 - \mathbf{1.2274}x_6 - \mathbf{2.0989}x_7 - \mathbf{2.9426}x_8\\ &-\mathbf{0.9611}x_9 + \mathbf{0.0366}x_{10} + \mathbf{0.1642}x_{11} + 0.0438\end{aligned} \tag{4}$$

$$\begin{aligned}\hat{y}_5 = &-\mathbf{0.0288}x_1 + \mathbf{1.8311}x_2 - 0.2136x_3 - 0.2655x_4\\ &-1.6070x_5 - 0.1538x_6 - \mathbf{0.5218}x_7 - \mathbf{1.3650}x_8\\ &-0.1501x_9 - 0.0042x_{10} + 0.0076x_{11} + 0.0131\end{aligned} \tag{5}$$

The regression coefficient of HR (x_1) in these multiple regression equations is significant in all equations and its sign is negative in all of them. In other words, the lower the HR, the larger the difference in brain waves (β/α). From previous studies, differences in EEG can be described as differences in difficulty which means that HR decreases when difficult problems are tackled. As with HR, anger (x_2) is significant in many equations and its coefficient is positive in all of them. The more the expression of anger appears, the larger the difference in (β/α). In other words, there is a positive correlation between an increase in the expression of anger and an increase in the level of difficulty. This result fits the study's intuition. Surprise (x_8) is also significant in many equations, and since its coefficient is negative, the higher the surprise, the smaller the difference in brain waves (β/α). This can be interpreted as a reduction in (β/α) due to surprise or giving up because the task was too difficult.

4.2 Analysis Using Cross-validation

In the previous subsection, the regression equation was evaluated using the coefficient of determination (contribution ratio R^2). However, there is a possibility of overfitting due to the small number of samples in relation to the number of explanatory variables. Therefore, it is necessary to separate the sample data into training data and evaluation data.

Method of Validation. This time, for selecting explanatory variables, a multiple regression fraction is obtained by round robin (all combinations of 11 types of explanatory variables). Cross-validation is performed for the 27 experimental data with each combination of explanatory variables using the leave-one-out cross-validation. Particularly, one out of the 27 was used as test data with the remaining 26 used as training data. Multiple regression analysis was performed using 26 data to obtain a regression equation. The test data was applied to the regression equation to obtain the predicted value. The difference between the predicted and measured values was calculated. This was repeated 27 times to obtain the RMSE. These 27 iterations were performed for all combinations of explanatory variables to find the optimal combination (i.e. the combination with minimum RMSE). The RMSE is expressed as follows:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_{obs,i} - y_{pred,i})^2} \tag{6}$$

Here, $y_{obs,i}$ is an observed value, $y_{pred,i}$ is a predicted value.

Validation Result (RMSE). Results in the previous section may be overfitting due to the small sample size. In this section, leave-one-out cross-validation is carried out on all combinations of the 11 explanatory variables for the selection of explanatory variables using 27 sample data. The combination of explanatory variables that minimizes RMSE is then obtained. The combinations of explanatory variables with the minimum RMSE and multiple regression equations using the explanatory variables are shown in Table 4. Meanwhile, Table 5 shows the value of RMSE for each objective variable.

Table 4. Combination of explanatory variables with minimal RMSE

Objective variable	Explanatory variables
β_l/α_l (y_1)	HR(x_1), contempt(x_3), disgust(x_4), fear(x_5), joy(x_6), sadness(x_7), surprise(x_8), neutral(x_9), engagement(x_{10}), valence(x_{11})
β_h/α_l (y_2)	HR(x_1), anger(x_2), disgust(x_4), joy(x_6), sadness(x_7), surprise(x_8), valence(x_{11})
β_l/α_h (y_3)	HR(x_1), anger(x_2), fear(x_5), joy(x_6), neutral(x_9), engagement(x_{10}), valence(x_{11})
β_h/α_h (y_4)	HR(x_1), anger(x_2), contempt(x_3), disgust(x_4), fear(x_5), joy(x_6), sadness(x_7), surprise(x_8), neutral(x_9), engagement(x_{10}), valence(x_{11})
β_{l+h}/α_{l+h} (y_5)	HR(x_1), anger(x_2), contempt(x_3), disgust(x_4), fear(x_5), joy(x_6), sadness(x_7), surprise(x_8), neutral(x_9), engagement(x_{10})

It can be seen in Table 5, that the RMSE value of the objective variable y_4 is larger. Also, from Table 4, the number of explanatory variables for the same objective variable y_4 has not been narrowed down and all 11 explanatory variables are needed. These two facts suggest that the objective variable y_4 contains unexplained causes. For the other objective variables, the RMSE values are also smaller than in Table 5, and the number of explanatory variables can be narrowed down from Table 4.

$$\begin{aligned}\hat{y}_1 = &-0.0072x_1 + 0.2409x_3 - 0.3228x_4 + 4.6063x_5 \\ &+0.2140x_6 + 0.1784x_7 - 0.8902x_8 + 0.1308x_9 \\ &-0.0165x_{10} - 0.0455x_{11} - 0.0261\end{aligned} \tag{7}$$

$$\begin{aligned}\hat{y}_2 = &-0.0386x_1 + 2.3171x_2 - 0.6562x_4 - 0.0185x_6 \\ &-0.2389x_7 - 1.6664x_8 + 0.0251x_{11} + 0.0284\end{aligned} \tag{8}$$

Table 5. RMSE of multiple regression equations for objective variables (y_1 to y_5)

Objective variables	RMSE
β_l/α_l (y_1)	0.0464
β_h/α_l (y_2)	0.0977
β_l/α_h (y_3)	0.0572
β_h/α_h (y_4)	0.2131
β_{l+h}/α_{l+h} (y_5)	0.0781

$$\hat{y}_3 = -0.0099x_1 + 1.1495x_2 - 1.5951x_5 + 0.1795x_6 + 0.0940x_9 - 0.0150x_{10} - 0.0523x_{11} + 0.0049 \quad (9)$$

$$\hat{y}_4 = -0.0545x_1 + 3.8361x_2 - 1.4383x_3 - 0.5347x_4 - 9.5242x_5 - 1.2274x_6 - 2.0989x_7 - 2.9426x_8 - 0.9611x_9 + 0.0366x_{10} + 0.1642x_{11} + 0.0438 \quad (10)$$

$$\hat{y}_5 = -0.0286x_1 + 1.7935x_2 - 0.1994x_3 - 0.2688x_4 - 1.3494x_5 - 0.1279x_6 - 0.4994x_7 - 1.3307x_8 - 0.1351x_9 - 0.0054x_{10} + 0.0129 \quad (11)$$

5 Consideration

As demonstrated in the preceding section, as a result of this research, it is now possible to explain brain waves using HR and 10 different types of facial expressions.

In this experiment, we used a heart rate monitor that wraps around the chest, but smartwatch-styles heart rate monitors are also available. In previous experiments, we confirmed that a heart rate monitor wrapped around the chest and a smartwatch-styles heart rate monitor can produce nearly identical data. In terms of facial expressions, the fact that the learner's face is captured by the camera during the learning process may be distracting. Learning through cameras is becoming more common in online classes, which began with the COVID-19 outbreak. In this regard, the measurement of biological information (HR and facial expressions) targeted in this experiment is thought to be significantly less taxing on the learner than wearing an EEG.

Furthermore, based on the findings of previous studies that the learning state can be estimated by measuring brain waves, we attempted to explain brain waves with biological information other than brain waves in this study. However, the ultimate goal of the research is to directly estimate the learning state rather than to explain the brain waves. Smartwatches can now measure not only heart rate (HR) but also heart rate variability (HRV) and blood pressure. We would like to improve the accuracy of estimating the learning state by including other biometric information that can be easily measured in addition to heart rate and facial expressions.

6 Conclusion and Future Work

In this study, biological information was collected during programming learning and multiple regression equations that predict brain waves from heart rates and facial expressions were obtained. Cross-validation was used to select explanatory variables to find the optimal combination. Classical multiple regression analysis was employed with electroencephalography (EEG) as the objective variable while HR and 10 facial expressions (anger, contempt, disgust, fear, joy, sadness, surprise, neutral, engagement, and valence) served as explanatory variables. In a future study, machine learning techniques will be incorporated to perform analysis. In addition, further experiments to increase sample data using various biological devices will be conducted in order to improve accuracy and clarify the relationship with educational effect improvement.

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Research Ethics. The experiments were approved by the Research Ethics Committee of Shonan Institute of Technology. Consent signatures were obtained from examinees and the parents of the examinees regarding participation in the experiment.

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An Empirical Study to Predict Student Performance Using Information of the Virtual Learning Environment

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Abstract. This study aims to explore a new feature model and a set of machine learning classifiers to predict student performance by monitoring his/her activities on the Virtual Learning Environment (VLE). The features are used for training the classifier to predict the final result of each student. The proposed model is evaluated by using a dataset built at the Open University of London. The results show good performance (80% of accuracy) of the proposed approach compared to other similar studies.

Keywords: educational data mining · machine learning · virtual learning environment

1 Introduction

Recently the education sector shows significant development in the research field of Educational Data Mining (EDM) [1]. EDM is a discipline, which through the exploration of big data, deals with the development of methods to better understand students and learning contexts [2–7]. EDM also consists of adopting Machine Learning (ML) and predicting models to understand and overcome the student's behaviour and predict students' performance and students' dropout [9]. The advantages of the adoption of ML to predict student performance are several including the detection of failure risk for each student, the assurance of student retention, and the course and resource allocations [8]. The wide variety of modern educational contexts allows one to strengthen and multiply the research methods used, in fact, EDM deals not only with the simple exploration, research, and implementation of Data Mining (DM) methods, but it is often used for predicting meaningful models to improve knowledge not only of students but also of academic institutions in general [9]. Indeed, e-learning is the fastest growing form of education today; e-learning platforms such as Intelligent Tutoring Systems (ITS), Learning Management Systems (LMS) and Massive Open Online Courses (MOOC) leverage EDM in the development and construction of automatic grading systems and

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course recommendation systems. Furthermore, during the management of courses, these platforms collect valuable information about the user such as the frequency of access of a student to the platform, the accuracy of students' answers to exam questions, and the number of hours spent reading and viewing study materials, number of accesses to the platform, etc. This information acquired over time, is analyzed using Machine Learning (ML) methods; ML models, in fact, can analyze large amounts of complex data much more quickly and easily, obtaining accurate results and avoiding the use of complex algorithms [10]. In particular, through the use of ML it is possible to predict the performance of students at risk and not; determine and predict the dropout of students from courses; determine the corrective plans for the cases observed in the previous objectives [11]. In our study, we predict student performance through the use of a variety of data collected by the VLE of the Open University of London on 7 different courses. The prediction is calculated by evaluating the accuracy of 10 different classifiers, trained on a carefully chosen set of 18 features related to various information about the student such as demographic data, specific characteristics of the course and its interaction with the VLE. This paper is structured as follows: Sect. 2 provides an overview of existing literature on the subject, while Sect. 3 introduces the classifiers used and gives a description of them. Section 4 describes the approach used in this work, in particular, we reported a description of the raw data sets and of their pre-processing; a description of the final features model built and used to solve the classification problem, and the evaluation method used to choose the best classifiers. Section 5 summarizes all of the results highlighted and obtained as a result of this study. Finally, in Sects. 6 and 7, all potential threats to the study's validity and conclusions, as well as future research opportunities highlighted by our study, are depicted.

2 Related Work

A study conducted by the University of Bangladesh discovered that the number of private universities present today is much higher than the number of public universities [12]. This also depends on the possibility, given by private universities, of using the lessons and study materials autonomously and virtually [13]. These new realities also allow us to collect ever more detailed data on the student and his/her university life. Nowadays, several statistical and machine learning algorithms are applied and evaluated on this data; also because, predicting student performance as early as possible is not only useful for teachers so that weaker students can be identified and helped promptly, but also for the student himself [14]. To do this, various predictive methods based on classification, regression and categorization have already been analyzed in the literature. Among the various methods already examined, the classification is the one that shows the best results [15]. In particular, a study of Kapur et al. [16] display encouraging results using classification algorithms to predict student performance: through the breakdown into three categories of student achievement (high, medium and low), a data set of 480 items with 16 attributes and the use of Random Forest obtain an accurate forecast of 76.67%. Muchmore, multiple studies demonstrate that a student's outcome depends not only on his university skills, but also on internal demographic factors such as gender, age, family background, and disability and, on external factors [17–20]. In particular, the gender is important in learning process [21]; male and female students in fact, have many differences in studying process [22]. Particular emphasis is also given to factors such as extra-curricular activities [23,24], high school background [25,26] and, social interactions [18,27].

Supported by the research already carried out in the EDM field, the objectives of this work are many:

i) predict the outcome of the students' final exam through different ML algorithms;
ii) predict whether the student is at risk of failing the final exam or not;
iii) compare the results of the various machines learning forecasting techniques to identify which algorithm offers the best predictive accuracy.

Our study, however, compare with similar studies, uses much more data, and is more varied in fact, the information is derived from seven different courses and not from a single course; these choices were made to obtain estimates as close as possible to reality and not refer to particular situations.

3 Background

This section describes the classification approaches used in this study. We choose algorithms with different characteristics to predict the outcome of the student's final exam and to understand which family of classifiers is the one able to better predict. Classifiers are part of two large classes: simple classifiers that directly use the information contained within the features for prediction (such as logit, k-neighbours, support vector machine) and classifiers that belong to the group of self-learning algorithms (like the others used in this work). The latter class is based on iterative learning, a ML technique that starting from an initial forecast creates subsequent intermediate forecasts by implementing the information obtained from the previous forecasts, to build the final forecast as a result of all the previous forecasts and all the information acquired in the various iterations. In particular, we use:

– **Logit**, a binary classification model based on the probability of occurrence of the event. It is widely used in the ML because it also allows you to view the dependency relationships between the target and the features [28].
– **K-Nearest Neighbors** (KNN), a non-parametric technique considered 'lazy' [29] because it does not immediately learn from data thus taking a long time. The KNN algorithm uses the concept of minimum distance and for this reason, it is computationally complex.
– **Random Forests** (RF), meta estimators based on the decision tree, created on several sub-samples of the original data. This estimator uses the mean of the tree forecast to improve predictive accuracy and over-fitting. The forest is made up of random and unrelated trees [30].

- **Extra Trees**, meta estimator that fits a series of randomized decision trees (called extra trees) on various sub-samples of the source data. It is a variant of RF, for this it uses the average of the intermediate forecasts as the final forecast [31].
- **Support Vector Machine** (SVM), a technique that separates classes using an optimal hyperplane [32], and supervised learning. This algorithm delimits the decision in such a way that the separation between two classes is as large as one might reasonably expect; for this reason, SVM works best if the data size is small [33].
- **Multi-Layer Perceptron** (MLP), a feed-forward algorithm because the features used as input are combined in the various layers. Each layer is made up of one or more neurons. The data belonging to the input layer is analyzed through one or more hidden layers. This algorithm uses a non-linear trigger function and uses back-propagation for training [34].
- **Gradient Boosting** (GB), a particular boosting algorithm consisting of an advanced loss function to make predictions and an additive model to minimize the loss function. As the gradient increases, this technique can lead to an effective increase in efficiency and the elimination of over-fitting. GB is a mixed classifier where the decision tree technique and Boosting meet [35].
- **XGBoosting** or "eXtreme Gradient Boosting" (XGBC), a much faster, high-performance GB implementation. This tree-based algorithm uses a different loss function to control the complexity of the classification trees, relative to GB. In addition, XGBC uses several self-learning methods to increase the speed of tree building [36].
- **CatBoost** (CB), an implementation of GB. In addition to faster computation speed, it provides better results than GB when the target variable has multiple categories. Indeed, his name means "Category gradient amplification". To increase its robustness, CB constructs trees to approximate the gradient of the model through the use of multiple permutations [37].

4 Approach

This study proposes the adoption of ML binary classifiers to predict if the student passes the exam successfully from the analysis of a set of features extracted from data collected from the student interaction with the learning platform.

4.1 Raw Data Description and Pre-processing

The suggested approach is evaluated on a real data-set provided by the Knowledge Media Institute of the Open University. The publicly available data-set is obtained from different data sources containing information about 7 courses and 32593 students. The raw data consists of 7 different tables:

- **courses:** this data-set contains the list of all available courses and their presentations.

- **assessments:** this table contains information on evaluations in module submissions. Some courses feature a series of interim assessments from the final exam.
- **VLE**: this data-set contains information about students' interactions with the VLE. On the VLE there is material such as HTML pages, pdf files, etc. Access to online materials and interactions are recorded directly from the platform.
- **studentInfo:** this file contains demographic information about the students such as gender, age, disability, etc. In this table, there is also the final result obtained for the reference module and the number of times the student has attempted the module.
- **studentRegistration:** contains information on the exact time the student registered for submitting the form. For who decide to unsubscribe from the form, the date of cancellation is also recorded. In particular, the registration date is calculated by taking into account the number of days measured concerning the beginning of the submission of the form. The student is allowed to register for the submission of the form even before the form begins, for this reason, this characteristic can also assume negative values.
- **studentAssessment:** this data-set contains all the results of all student assessments. If the student fails, no results are recorded. The grade of each test is evaluated on a scale from 0 to 100; the test is passed if the grade is greater than 40.
- **studentVle:** this table contains other information about each student's interactions with the study materials in the VLE, such as the date of the student interaction and, the number of times the student interacts with the material on that particular day.

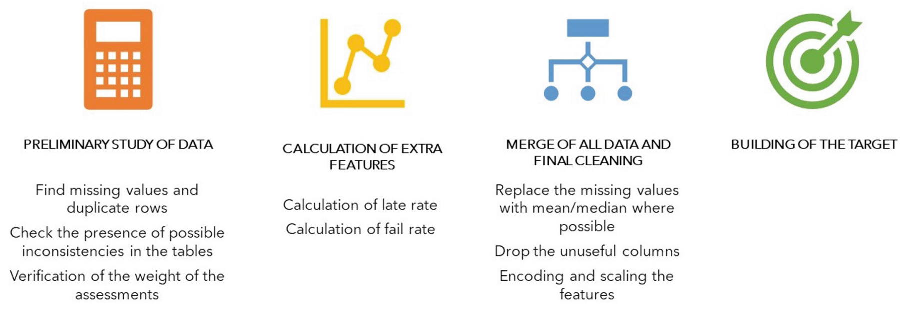

Fig. 1. Methodology of cleaning and feature engineering

Within them, the data present multiple problems such as missing values and duplicate rows. For this reason, extensive data cleaning and features engineering is performed. In particular, the cleaning of the original tables involved the following phases:

- **Preliminary study of the data:** in this phase, we viewed the data by table and verified the possible presence of missing values and duplicates; we have also carried out the verification of the weight of the assessment and, check the presence of possible inconsistencies into the tables.
- **Calculation of extra features:** we built two new features because into the raw data, the only variable that gives information about the result of the module is the score that represents the student's score in the final assessment. The score had a range from 0 to 100. To increase the set of features, we built the "fail rate" like the ratio between the total number of fails per student and the total number of assessments (some modules have more middle exams). The "fail rate" had a range from 0 to 1, and this is more interpretable and easier to read. Furthermore, for the students, there is the possibility to submit the exams with late, and the only variable that gives information about this, it is a dichotomous variable (TRUE/FALSE); we built the "late rate" that had a range from 0 to 1. It is a normalized feature that is calculated as the ratio between the total late per student and the total number of assessments per module.
- **Merge of all tables and final feature engineering:** we merge the various tables and replaced the missing values with mean/median where possible. We also encode and scale the features and, delete duplicate lines.
- **Building of target:** to carry out the classification we dichotomize the result on the final exam and thus create the target variable "result" which contains the two classes of interest Fail/Pass. In particular, the score of the final exam had a range from 0 to 100 and it is passed if the student takes a score higher than 40 (as suggested by the author of the data), otherwise is failed.

All the steps relating to the study phases are shown in Fig. 1.

Some interesting statistics about the clean data are reported in Fig. 2 in which the top left shows the distribution of student gender; the top right has reported the distribution of age in classes: the bottom left shows the graph of the distribution of the result in the final exam for gender; finally, the bottom right, the diagram of the distribution of the final exam scores per sex is shown.

The data set obtained is then split with a 70/30 ratio and analyzed using various classifiers (Sect. 3) to predict students' academic performance.

4.2 Features Model Description

The proposed features model is composed by 18 different variables:

- 6 socio-demographic features such as gender, region, education, imd, age, and disability;

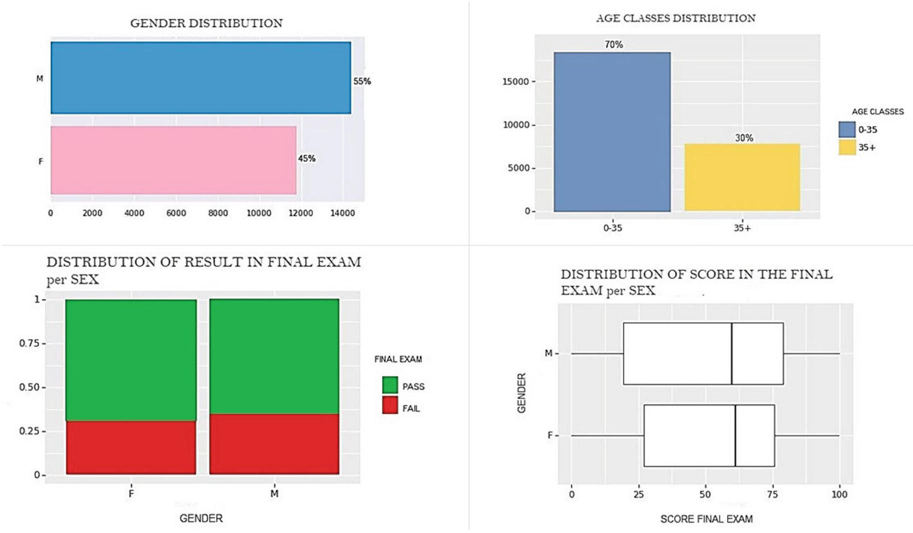

Fig. 2. Statistics about the clean data set

- 8 features about the course characteristics such as the type of assessment, the weight, and score of the assessment, the date the student enrolled and unsubscribed from the module, and the number of attempts the student had for the module;
- 4 features about the information on the student's interaction with the VLE and study effort such as the number of days the student interacts with the material and the number of clicks on the VLE on that day.

The binary classification (failure/pass in the final exams) for each student in each course considered is performed using the target feature "result" and the ML techniques described in Sect. 3.

All the features are described in Table 1 where in the first column is reported the name of the feature and in the second a short description of it.

4.3 Evaluation Metrics

To evaluate the various ML methods we use 4 different metrics such as:

- *Accuracy*: is the proportion of correct predictions.

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \quad (1)$$

- *Precision*: is the proportion of positive corrected predictions (TP) to total positive predictions made by the model.

$$Precision = \frac{TP}{TP + FP} \quad (2)$$

Table 1. The proposed features model

FEATURE	DESCRIPTION
module	Name of the module
presentation	Year and month for the presentation starting)
date	Date of registration of the student on the module presentation
module-length	Length of the module measured in days
gender	Gender of the student ("M"= male; "F"= female)
region	Geographic region where the student lives during the module
education	Highest education level of the student on entry to the module presentation
imd	Indices of multiple deprivation referred to where the student lives
age	Age of student in classes ("0–35"; "35+")
prevattempts	Number of times that the student is attempted the module
credits	Number of credits for the module
disability	The student declared a disability? ("N" = no; "Y" = yes)
click	Number of the interactions of the student with the material of the module
student	Unique identifiers of the student
unregistration	Number of days until the unregistration of the student from the module
score	Weighted score (student's score * weight of the module)
late-rate	Rate of delay in the delivery of the assignment submission
fail-rate	Rate of fails for the exams of the module
result	Final result of the student ("Fail" or "Pass")

– *Recall*: is also known as sensitivity and is defined as the ratio of corrected positive predictions (TP) to total positive instances.

$$Recall = \frac{TP}{TP + FN} \tag{3}$$

– *F1-Score*: is the harmonic mean of the Precision and Recall metrics, and it is used to compare ranking models.

$$F1Score = 2 \cdot \frac{Precision \cdot Recall}{Precision + Recall} \tag{4}$$

5 Empirical Study Results

This Section reports the results obtained using ML algorithms to perform the classification.

The results obtained from the features model (Table 1), are shown in the Table 2; the Table is constructed by placing the name of the classifier used in the first column, the accuracy obtained on the train set (70% of the data) and the result in terms of accuracy obtained on the test set (30% of the data) is shown in the second column, in the third column we reported the values of the precision metric both on train and test set, the values of the recall metric can be found in the fourth column, and in the last column are show the values of the f1-score.

The results (Table 2) show a good accuracy for all classifiers considering that these are real data highly varied between them. In particular, the classifiers that prove most accurate on both the train-set and the test-set, are provided by iterative methods with strong self-learning capabilities such as Random Forest, Multi Layers Perceptron and Boosting methods (the results of these techniques are reported in bold in Table 2). These classifiers provide also good performance in terms of precision, recall and f1-score.

The best predictor of the outcome of the final exam among all the classifiers is the Cat Boosting algorithm which shows a predictive accuracy of about 80% both on the train and on the test set.

The results of this study are excellent compared to those obtained by research to date. Our predictions are about 80% accurate. Furthermore, our work takes into account a large number of students (more than 32000) and from different courses (7 different courses were matched) compared to similar studies that obtained lower estimates despite using a much smaller data set [38–40].

Table 2. Evaluation metrics of the considered classifiers in predicting students' performance

ML CLASSIFIER	ACCURACY		PRECISION		RECALL		F1-score	
	TRAIN SET	TEST SET	TRAIN SET	TEST SET	TRAIN SET	TEST SET	TRAIN SET	TEST SET
LOGIT	0,75	0,75	0,74	0,74	0,75	0,75	0,75	0,75
KNEIGHBORS	0,70	0,70	0,70	0,70	0,70	0,70	0,70	0,70
RANDOM FOREST	0,78	0,78	0,79	0,78	0,79	0,78	0,79	0,78
EXTRA TREES	0,74	0,75	0,73	0,74	0,74	0,73	0,73	0,74
SVC	0,66	0,66	0,65	0,64	0,64	0,64	0,64	0,64
MLP	**0,78**	**0,78**	**0,79**	**0,79**	**0,78**	**0,79**	**0,79**	**0,79**
GRADIENT BOOSTING	0,71	0,71	0,70	0,69	0,70	0,70	0,71	0,71
ADA BOOSTING	**0,78**	**0,77**	**0,78**	**0,78**	**0,78**	**0,77**	**0,77**	**0,77**
XG BOOSTING	**0,78**	**0,78**	**0,78**	**0,78**	**0,78**	**0,78**	**0,78**	**0,78**
CAT BOOSTING	**0,80**	**0,79**	**0,81**	**0,80**	**0,80**	**0,80**	**0,80**	**0,79**

6 Threats to Validity

This Section reports the possible threats to the validity of this work, such as the possibility of inconsistencies in the relationship between the theoretical world and what we observe.

In this study there is a threat to internal validity, referring to factors internal to our work that can influence the results obtained. In general, we cannot expect to mitigate the chance relationship between the outcome of the final exam and the student's activities with the VLE. To mitigate this effect, we took into account the results of all students.

There is also a threat to the generalizability of the results of this study. To mitigate this threat, not the data relating to a single course of study but to seven different courses are considered, to obtain an overall population as close to university realities. The generalizability of the results is also an external threat, which we undertake to mitigate with future works, the results of which may consolidate or deny this work.

7 Conclusions and Future Work

This work provides an overview of the adoption of ML classifiers for a priori prediction of the outcome of the final exam.

Our study demonstrates that the use of ML algorithms effectively predicts the outcome of the student through a few simple variables, easily collectable by the VLE. In particular, the results obtained show that the best classifiers are iterative ones based on self-learning such as the RandomForest and Boosting methods.

The best prediction is returned by the Catboosting algorithm with an accuracy of 80%, trained on the sub-sample subdivision of 70/30 and, a maximum depth of the tree of 5.

In future work, we want to explore not only new features but also augment the existing data-set. A larger data-set could also be useful not only for exploring new ML approaches but also for use with more complex Deep Learning techniques.

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Do 5W+H Commute? Examples in Calculus and Communication of Science

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Abstract. Scientific communication relies on two main different structures, the IMRAD (Introduction Methods Results Analysis Discussion) and the 5W+H (Who Where Why What When How). The former is quite rigidly applied to all peer-to-peer communication, while the latter appears more loosely adaptable to dissemination and communication to the general public. We analyzed the evolution of the content of Calculus books widely adopted in Italian scientific academic courses over the past sixty years and the syllabus of a Communication of Science short course offered by the University of Bari in the last three years. We conclude that the 5Ws can be commuted to some extend with no harm to final result, while the same does not hold for the H that should always remain as the final question. Notwithstanding this flexibility, it is compulsory to answer to all 5Ws and H questions for effective communication.

Keywords: Science Communication · Distance Education · Learning Outcomes

1 Introduction

We have been taught two non-trivial things since primary school: the commutative property of addition in mathematics and the 5W+H rule in telling.

The commutative property of addition depends on the meaning we attribute to the noun *addition*. Thinking of *addition*, we immediately focus our attention on numbers whose addition is commutative $5 + 3 = 8 = 3 + 5$. Yet, going beyond the implicit reference to numbers, non-commutative relations become frequent. The classic example comes with the use of letters, where the *addition* operation means arranging the letters one after the other. It immediately pops up that $o + n = on$ is different from $n + o = no$. This is a beautiful example often proposed to primary school students to emphasize how special the commutative property of the addition between numbers is and that nothing should be implicitly assumed. This concept is also emphasized in the book written by Giorgio Parisi to popularize his studies that led him to the Nobel Prize in physics in 2021

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[1]. The commutative property is trivial also for the *multiplication* among numbers, but it is violated, for example, by the *multiplication* among matrices and operators in general.

In quantum mechanics, by far the most precise theory we developed about the functioning of the world at atomic and molecular scale, measurable quantities are mathematically described by matrices and are then non-commutative, leading to the famous principle at the foundation of quantum mechanics known as the Heisenberg's uncertainty principle (see, for example, [2] and references therein). The principle sets a limit about the knowledge we can get about some basic properties describing any physical system, like energy (E) and time (t). The principle does not focus on the value of these properties, but on the accuracy (ΔE and Δt) with which this value can be ascertained. Its mathematical formulation $\Delta E \Delta t \geqslant \hbar$ states that it is impossible to have, simultaneously, full knowledge of the energy associated with a configuration of the system and of the moment when the system has that specific energy; it is only possible to reach a minimum uncertainty about both. If we wanted to gain a more precise knowledge of energy, this would necessarily be at the expense of a more inaccurate knowledge of the time at which the energy has that specific value. Pietro Greco extended Heisenberg's uncertainty principle to the communication realm [3]. Let $\mathrm{r} =$ rigor and $\mathrm{c} =$ communicability, one has $\Delta \mathrm{r} \Delta \mathrm{c} \geqslant \mathrm{k} > 0$, meaning that in popularization of science it is impossible to get the maximum of the rigor ($\Delta \mathrm{r} = 0$) or the maximum of the communicability ($\Delta \mathrm{c} = 0$), at the same time. Greater communicability requires less rigor and, conversely, greater rigor leads to loss of communicability. In the context of this theoretical framework, we argue that communicative paradigms are non-commutative at some level of structure, and we specialize the discussion on the communication of science.

The structure adopted in scientific communication for minimizing the above inequality is not unique, it changes according to the audience and is also informed by the underling model for public communication of science and technology (PCST) [4, 5]. The IMRAD framework: Introduction, Method, Results, Analysis and Discussion, for example, is assumed as the gold standard in communication among peers. The order of these stages is rigorous (non-commutative) and it helps both the author and the public to optimize the value of $\Delta \mathrm{r} \Delta \mathrm{c}$ of their communication. However, other narrative frameworks are possible and well described by Daniele Gouthier in [6]. In the dissemination of science, for example, the 5W+H narrative structure: *Who*, *What*, *Why*, *When*, *Where* and *How*, is considered more effective than IMRAD. More frameworks are also possible as clearly described by Blum et al. [7].

A good example of the use of different codes to communicate the same news in different contexts is provided by the recent disclosure of the shadow of the supermassive black hole in the center of the Milky Way. The first communication appeared in The Astrophysical Journal Letters, on May 12, 2022. Titled "First Sagittarius A* Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole in the Center of the Milky Way" [8], the publication duly follows the IMRAD code. On the same day, The Harvard Gazette published the news titled "First image of black hole at the heart of Milky Way" [9], whose first sentence is "An international team of astronomers led by scientists at the Center for Astrophysics | Harvard & Smithsonian who produced the first direct image of a black hole three years ago have now produced a portrait of a second, this time a much-anticipated glimpse of one at the heart of the Milky Way."

The order of *W*s is *Who-Where-When-What*, the *How* is given in the second sentence and the *Why* is suggested only at the end of the news. Again, on May 12, Nature, one of the leading European science journals, published "Black hole at the center of our Galaxy imaged for the first time" [10], whose first sentence is "Radioastronomers have imaged the supermassive black hole at the center of the Milky Way. It is only the second-ever direct image of a black hole, after the same team unveiled a historic picture of a more distant black hole in 2019." The order of *W*s is here *Who-What-Where-When*, the *Why* is suggested in the following sentence and the *How* is given even later on. While the IMRAD code is quite rigidly adopted in all peer-to-peer scientific communication, whether oral presentation or written paper, there can be found numberless examples of different ordering of the 5W+H in science dissemination to the general public.

In this paper we discuss the commutativity of 5W+H discussing two examples of the structure of a science teaching course. In the first example, the structure of Calculus courses in Italian universities is analyzed through the content of some representative textbooks. The second example is based on the outcome of three online editions of *Communication of Science* course given by the authors at the University of Bari in the last three academic years.

2 Do 5W+H Commute? - An Example from Calculus Course

It is somewhat obvious that communicating formal knowledge to students requires adopting a different paradigm than IMRAD [11]. The analysis of the program structure of teaching courses according to the 5W+H guiding model starts with defining the questions in this context:

- *Who* identifies the objects of the course.
- *What* reveals the actions and the relations among these objects.
- *Where* develops graphical representation of the relations.
- *When* accounts for a diachronic approach to the discipline.
- *Why* provides examples and evidence of applications.
- *How* suggests strategies for using the acquired knowledge in different contexts.

They may not be the unique nor the best possible definitions but are broad enough to be applicable to different disciplines, including the first course of Calculus at undergraduate level, typically one the first teachings offered in any STEM course at university level.

The evolution of knowledge treatment in Calculus textbooks has already been studied (see for example ref. [12]), but we have adapted the 5W+H scheme to this topic:

- *Who* - The objects of the course are the numbers, the concepts of limits, continuity, derivatives, and integrals.
- *What* - The relations among the objects are the theorems and their proofs.
- *Where* - The graphical representations, graphs of functions, flow charts, etc.
- *When* - The chronological approach from history of science. For example, citing Archimedes intuitions before the Cauchy-Weierstrass formulation, or to mention the Archimedes and Cavalieri ideas before the lessons on Riemann integrals.

- *Why* - The motivations of the derivatives, for example, can be related to optimization problems often found in every discipline. Analogously, the discrete diffusion phenomena, similarly to population models, become a motivation for studying sequence.
- *How* - Students apply what they learned during lessons to exercises to become familiar with limits, derivatives and integrals.

Not being interested in a statistical comparison, rather to identify the general trends, we do not directly compare the course syllabi, but the content of popular textbooks they were based on, as reported in Table 1.

In the old book [13] by Carlo Miranda written in 1958 and widely used throughout the sixties, all the material focuses on the *Who* and the *What* questions that form the core of the discipline and were presented in a very formal way. About twenty years later, the *How* and the *Where* appear on the pages of the Calculus textbooks [14, 15]. Exercises and graphs are sprayed over the pages, but also other visual tools, like conceptual maps, are used helping the student to understand, for example, where the completeness axiom of the real numbers comes into play. Once again, about twenty years later, the *When* and the *Why* [16, 17] also appear on the scene, with applications, solved exercises and even images of great mathematicians.

Table 1. Classification of the Calculus textbook content according to the 5W+H scheme.

	Sixties	Nineties	Actual
Who	Complete description of numbers, limits, derivatives, integrals	Complete description and more difficult concepts in final sections of the chapters	Complete description and more difficult concepts in final sections of the chapters
What	Many theorems, all proved	The most difficult theorems are proved separately	Many theorems, some more difficult proofs are avoided
Where	Few function diagrams and no conceptual maps	Many function diagrams and geometrical schemes for examples and explanations	Many diagrams. Use of color coded pages
When	Absent	Absent	Some hints at the beginning of the chapters
Why	Few motivations, no applications	Few mathematical motivations, no applications	Few mathematical motivations and applications to physics
How	Few examples. Exercises are given in a separated book	Many examples, every chapter has a list of exercises	Many examples and exercises. For each kind of exercise at least one is solved

The order of the whole content of the book is generally preserved in each chapter, where the new *features* add on at the beginning and at the end of the core:

- *Who* - *What* in Ref. 13
- *Where* - *Who* - *What* - *How* in Ref. 14 and 15
- *When* - *Why* - *Who* - *What* - *Where* - *How* in Ref. 16, or, occasionally, the *How* can anticipate the *What*.

The core of the discipline is formally coded by the sequence *Who* - *What,* that is preserved during the years. The adds-on follow a less templated ordering and contribute to transforming a rigid course structure to a more narrative program. All these textbooks are clearly useful for learning calculus, although the most recent ones are also useful for motivating the students. Indeed, the surveys on “students’ opinion on teaching” recently adopted in the Italian university system often include a specific question on the motivational aspects characterizing teaching [18].

3 Do 5W+H Commute? - The Example of *Communication of Science* Course

Let us apply the previous argument to communication of science courses. First, we redefine the questions in this context.

- *Why* do you want to communicate your message, and why should it be interesting for someone*?*
- *What* are you going to communicate, what is the core message*?*
- *Who* would your audience be and what their expectations are?
- *Where* among the different available media channels are you going to deliver your message on: social media, blogs, newspapers, scientific journals*?*
- *When* is the right time and schedule of communication for your message, both in terms of editorial plans and calendar of events*?*
- *How* concerns the communication strategies (visual identity, brand protection, marketing), and the technical skills of image creation and video making.

It is somewhat a matter of cultural conditioning to decide which one comes first. It is often recognized that moving from the eastern to the western regions of the world the *How* (it would be better to do it) is replaced by the *Why* (should it be done) and then *What* (should be done) as the first question [19].

3.1 Motivation of the Case Study at University of Bari

In 2020, a few weeks after the outbreak of Covid-19 pandemic, the University of Bari “Aldo Moro” launched its first course *Communication of Science* that has now reached its third edition with an overall number of enrolled students nearing one hundred.

Following the analysis of the first [20] and the second [21] editions, in the third edition the content was rescheduled according to the feedback by students of the previous years.

Here we present the analysis of the online course structure that has been adapted over the years, comparing the three editions against the order chosen in the 5W+H structure and summarized in Table 2.

The first edition was planned with no external constraints on its duration and after a careful selection of the course content, eventually completed in 6 CFU. Basic principles and motivation, as we are formed by Greek philosophy, came first, and the practical skills ended last.

Table 2. Ordering of the program sections identified by the 5W and H in the three editions of *Communication of Science.*

1st	2nd	3rd
Why	*Why*	*Why*
Where	*Where*	*How*
What	*Who*	*Where*
Who	*What*	*When*
When	*When*	*Who*
How	*How*	*What*

The "main course", concerning the *Who* and the *What*, can be represented by the 3x3 matrix shown in Table 3, where cell entries specify the products of the handovers and homework. The axes were identified with the type of audience and with the communication modality mainly used in that context. The public, intended as the target of communication, was distinguished into three classes: *General Public*, often perceived as the anonymous subject of informal communication; *Stakeholders*, deserving a formal and often templated communication; *Peers*, typically sharing a disciplined style of communication. Among the different communication modalities, three were selected because of their substantially different lexical codes: *Writing* (for the web, news, scientific journal), *Speaking* (at conference, on video, as self-presentation) and *Drawing* (poster, schematic, logo). The products of the individual and group homework assigned during the course were designed as a training towards the final creation of a media event for the general public presented on a social platform on May 16, on occasion of the International Day of Light promoted by UNESCO. The event was titled *LumineScienza,* a name maintained over the years. However, the course syllabus and duration changed over the three editions, in response to the feedback provided by students [20] and format constraints from the institution.

Table 3. Core content of the first edition of *Communication of Science*.

What \ Who	General public	Stakeholders	Peers
in writing	short story	project proposal	scientific paper
in speaking	video	pitch	seminar
in drawing	logo & payoff	canvas	poster

The second edition maintained a similar framework, apart from the "commutation" of *Who* and *What* in the course schedule, while the third edition extended to only 4 CFU and a selection of the core content was necessary, with a consequent focus on the first column of Table 3 and a proportional resizing of the other contents. The preparation and content creation of *LumineScienza* had been reported as "demanding" by the students of the first two editions of the course, mainly because of the short time allowed to "digest" the *When* and the *How* technical feeds. For this reason, the course content was also rescheduled by allowing more hours to and anticipating the making skills (*When* and *How*) before the core content (*Who* and *What*), in the last edition.

3.2 Data Analysis of the Case Study

We are going to identify and compare some figure-of-merit in the effort of answering the question posed in the title. We are allowed to do so because the composition of the three classes shows a remarkably similar distribution in terms of all the relevant parameters: numerosity, gender, motivation, area of interest, as shown in Fig. 1.

Data for the three years were collected at the beginning, during and at the end of each course. Upon enrollment, students were asked to fill in a registration form consisting of data on gender, scientific interest and motivational information. The mid-term feedback form collected data on perceived study effort, global satisfaction and the program, organization and content of the course (on a 5 levels scale). The same questions were asked at the end of the course, together with additional ones related to the self-assessment of the achievement of the learning objectives and the *LumineScienza* experience. The intermediate and final questionnaires were anonymous.

The data was analyzed to evaluate the evolution of student satisfaction with respect to the outcome of the assignments and the final *LumineScienza* event. Given the relatively small number of students, correlations for the breakdown by gender, educational attainment, or motivation were not statistically relevant and data was analyzed aggregated for the class as a whole.

In summary: female students have been constantly more numerous than male's with an increasing percentage, in line with the composition of the UniBa total enrollment; students from scientific macro areas, PE and LS, sum up to about 90% of the classes while they represent about 40% of UniBa student population; students motivated by CFU constitute nearly half of the classes and their percentage increased over the years following the diffusion of information about the course, primarily, by word-of-mouth among students.

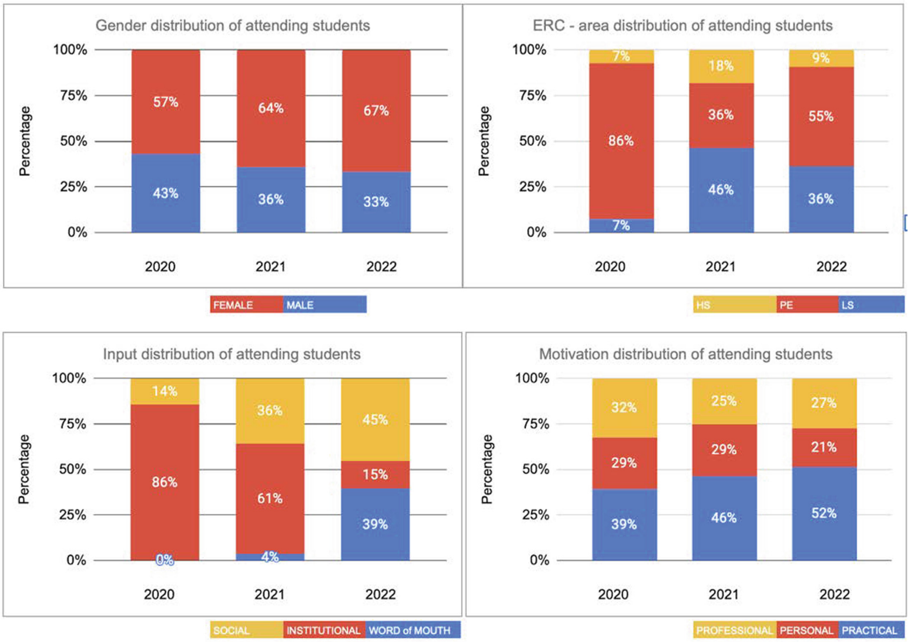

Fig. 1. Class composition in terms of binary gender (female, male), interest (ERC macroarea Life Science, Physics and Engineering, Humanities and Social studies), motivation (practical, as instrumental to the acquisition of CFUs - personal, for those who declared curiosity or passion for the subject of the course - professional, for those who already had experience in science communication), and the input information channel they heard about the course (word-of-mouth, institutional and social media)

The class composition partly reflects the way *Communication of Science* was intended for and communicated. The first year, the course was structured as a cycle of seminars, sponsored by the School of Science and Technologies of the University of Bari "Aldo Moro", open to the broadest participation of interested individuals regardless their enrolment at the organizing University. The initiative was diffused on the institutional channels (internal distribution lists, web pages of the domain, student representatives, posting of posters on the notice boards of the departments) and the social ones (*Facebook/ComScienza* page with sponsored campaigns, posts on groups of potential interested users). In the following years, internal communication was strengthened, following the promotion of soft skills development by the University of Bari under the program *Competenze Trasversali* (transversal skills). We do observe, though, that word-of-mouth and dissemination on social media have been more effective than internal institutional communication.

A traditional assessment test was not considered to enroll the course, even if prospective students were asked to fill a registration form. The number of registered students was much higher than those who eventually attended the course, and their "natural selection" occurred within the very short time required for them to realize the level of engagement required to guarantee active participation to individual and group homework and for the organization of *LumineScienza*. The results of the course transit are summarized in Fig. 2, where data indicate a progressive stabilization of the attendance.

Despite an average comparable diligence in task completion and quality of the evaluated homework, in 2022 Writing assignment had the lowest grade, nearly 20% less than previous edition, and Public Speaking had the lowest return rate (76% from about 85% of the previous years). It is worth noting that the Writing assignment follows the *What* section, and the Public Speaking assignment follows the *Who* section.

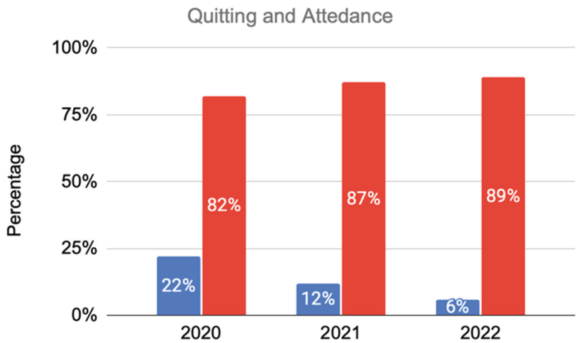

Fig. 2. Average attendance in terms of participation to the programmed hours and Quitting in terms of number of students with respect to those attending the first lecture.

At the end of each year, a feedback form consisting of both open and closed questions was proposed to students to be returned either signed or anonymous. Among the questions, we select the following for the purposes of the present analysis: "How does the level of commitment required by the course compare to expectation?"; "To what extent did you meet your learning goals?"; "Were the course contents adequate and properly organized?"; "Did the duration of the course match the content?". All the questions were answered on a 5-level scale, with neutral being in the middle. Graphs in Fig. 3 detail the results, that can be summarized as follow:

- Perceived study effort was increasingly considered more affordable (=);
- Learning objectives were largely achieved, however, full satisfaction (>>) dropped by 30% in the last edition;
- Course program was considered well organized in 90% of returned forms, however, full satisfaction decreased by 10% in the last edition;
- Course schedule was considered well organized in 80% of returned forms, however, full satisfaction dropped by 20% in the last edition.

The considerably positive overall results do not hide the worse figures of the last edition, as emerged also by the Global satisfaction index, which decreased by 10%.

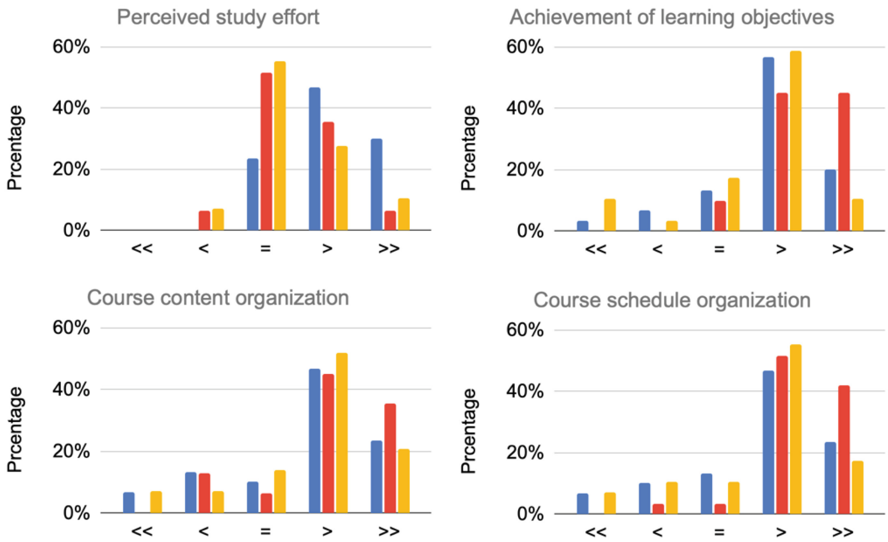

Fig. 3. The color legend and horizontal axis for all panels are the same: blue, red, orange for the 2020, 2021 and 2022 editions of *Communication of Science*, respectively. $<<$ not at all satisfied; $<$ not satisfied; $=$ as expected; $>$ very satisfied; $>>$ absolutely satisfied.(Color figure online)

3.3 Implications

Communication of Science can also be considered a kind of training for *LumineScienza.* It is emphasized from the first lesson that the final goal and the realization of the knowledge and skills acquired during the course, is indeed the creation of a web-based event on May 16, International Day of Light.

The three editions of *LumineScienza* were organized in different formats, partly because of directions provided by the organizers and partly by autonomous choice of the students, who planned, organized, registered, advertised the event, and created all the online content. A new *Facebook/luminescienza2020* event-page was created for the first edition, while the second and third editions were posted on the *Facebook/ComScienza* official page. The budget for sponsored posts was roughly the same, but *Facebook* algorithms and rules have changed in these three years, together with the social and individual 'mood'. A detailed look at Fig. 4, where the visibility achieved by *LumineScienza,* as measured by the number and type of interactions on the platform, is summarized, will help to answer tentatively to the question "Do 5W+H commute in communication of science?".

Average number of interactions per published post and average visualizations per posted video on May 16, both decreased sharply in the last edition. Also, the number of new followers decreased from almost 2000 to about 200, in spite of the first edition having its own newly created page, starting from zero, and the other two editions being built on the existing followers of the official *Facebook/ComScienza* page. We believe that this counter intuitive response is somewhat dependent on the course schedule.

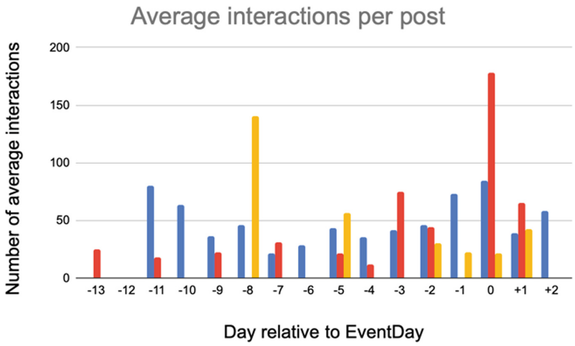

Fig. 4. Comparing *LumineScienza* editions on Facebook metrics. Day 0 is May 16. Color code is the following: Blue is relative 2020 edition, Red to 2021 and Yellow to 2022.(Color figure online)

It is well known that videos posted on social media always receive about ten times higher interactions than photos or text-only posts. This behavior is also evident in the first two editions, where videos received on average 711 and 644 visualizations, while the other posts 45 and 31 interactions, respectively. Even if the *How,* the *Where* and the *When* (making a video and programming a social event) were anticipated and were given more relevance in the third edition, students chose to rely mostly on static posts both in the warm-up phase and the delivery of *LumineScienza.* We argue that this is due to moving the *What* and the *Who* sections to the end of the course and reducing the hours devoted to them, meaning that the Message is more relevant than the medium, in contrast to McLuhan's idea that "the medium is the Message". In comparison with the second edition, for example, when video and writing assignments had concerned the history of science, in the third edition students were allowed to choose their own subject. As a possible consequence, *LumineScienza* inherited the somewhat sparse in depth-contents of each student instead of a common background. The common background also developed in the first two editions thanks to a constant push towards team working: focus-groups were organized from the beginning and on-purpose inhomogeneous smaller groups created the intermediate and *LumineScienza* deliveries. In the last year, there was less push towards team working and students self-organized the *LumineScienza* collaboration assigning small individual tasks to everyone and making a "control room" with only a few members.

As a further indication of the relative relevance of teamwork versus technical skills, the students' feedback on their commitment to technical skills development and teamwork is summarized in Table 4. The efforts made to build a collaborative group in 2021 were rewarded with a surprisingly high degree of satisfaction, which also supported the challenging task of creating media contents. On the contrary, group collaboration was considered quite demanding among the students of the last edition, with negative repercussions also on the creation of social communication contents.

The above results and considerations will have practical implications in the shaping of the next editions of *Communication of Science.* Priority will be given to building teams and 'provoking' collaboration since the beginning. The relatively short duration of the latter course edition recommends a balanced approach between autonomy and guidance in the making of the *LumineScienza* event, if it has to broadcast the learning outcomes.

Some theoretical implications can also be deduced: it appears evident that the practical skills (the *How* and *When*) must be answered only after the basic questions: *Why* do you want to communicate your message? *What* are you wish to communicate? And *Who* would the audience of your message be? Although not presented in detail in this communication, the analysis of the homework scores advocates for a nearer, in time, and closer, in content, assignment with respect to the lecture program.

Table 4. Students comment about their perception of team working and practical skill development activities

	2021			2022		
	Demanding	Surprising	Exciting	Demanding	Surprising	Exciting
Technical Skills	13%	50%	37%	30%	50%	20%
Team Working	0%	77%	23%	60%	23%	17%

4 Conclusion

We have produced some evidence that the order of the 5Ws has limited impact on the outcome of the narrative, as well as on the learning outcome of *Communication of Science*. Answering to the interrogatives posed in the title, they do commute to some extent. On the other hand, the commutation H+5W did not return the same results of 5W + H. We observed more satisfactory learning outcomes when the course content followed the traditional "Ws first and H last narrative", and analyzed that the *How* typically follows at the end of a course program in modern calculus textbooks, where the order of 5W+H is also usually maintained in every section of the program to reinforce the coherent narrative.

As inappropriate as it may seem at first glance, analyzing formal course programs through the lens of narrative structure should not be considered profane. Gabriele Lolli in Ref. 22 writes: "message communication in fairy tales is direct and convincing, and the rules of storytelling can be applied in a fairly effective way both for teaching and for disseminating scientific content".

Coming back to Pietro Greco's version of the uncertainty principle, (see Sect. 1), we are gaining awareness that the optimal balance between communicability and rigor is quite "a thin red line". However, physicists do not stop looking at particles because of the limitations of the uncertainty principle, they use the principle to make better guesses. We believe that the "uncertain" commutativity of 5W+H should not prevent teachers from looking for the optimal structure of their course, rather they should exploit this flexibility to explore didactic innovations.

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Harvesting Metadata for XR Digital Learning Objects

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Abstract. The current work is a proposal for Moodle administrators who aim to provide content creators and teachers with capabilities to describe in a semi-automatic way their learning resources with LOM-based metadata and make these metadata available to search service providers so that other stakeholders can easily find and retrieve them. It was composed within ARETE project to support reusability and discoverability of 3D/AR and other types of educational resources included in the project's Moodle digital repository.

Aiming on utilizing previous work on this domain, the code of two existing plugins was modified and enriched to serve the project's needs. This paper aims to demonstrate in detail two plugins that will be utilized in ARETE's Moodle digital repository to support the discoverability of learning resources by creating and exposing their metadata to make them available for harvesting. The content in the ARETE repository is particularly relevant to 3D/AR learning activities created through an XR authoring toolkit. Nevertheless, educational content in other formats continues to be supported by the aforementioned plugins.

The integration of IEEE-LOM and OAI-PMH standards to a Moodle repository seems to be a feasible way to enhance the development of learning content by utilizing relevant already existing resources that can be easily found and retrieved. However, the difficulty of finding service providers that could support the collection of learning resource metadata and be willing to build search engines on top of them suggests the need to consider different approaches.

Keywords: Learning Objects · Metadata harvesting · Digital learning repositories

1 Introduction

Standardization and data analytics in education aim to support and improve educational systems by handling, managing, analysing and interpreting data concerning the educational process. Widely used standards are used in online education to describe learning content, capture student activities, enable interoperable communication between heterogeneous systems, and ensure data privacy. In addition, standardization efforts for computer-based learning support

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resource discovery and access, including brokerage services and harvesting, and educational metadata [1].

Learning resource is a common denominator of many Educational Data Mining and Learning Analytics (EDM & LA) activities since it is a starting point on which other relationships can be built on. For example, there is no point of trying to analyse the interactions between a student and a Learning Object (LO) when the resource has not been defined or the student had not had the chance yet to find and retrieve it. The accompaniment of LOs with metadata files which are capable to provide a clear and successful description of resources, could enhance their discovery, acquisition, interoperability and reusability.

Augmented Reality (AR) technology has been presented as a valuable tool for enhancing students learning by many studies [2–6]. The terms AR, VR, and MR often appear together as technologies that produce or modify reality. XR is an umbrella term for all of the aforementioned realities. Although research has shown that XR effectively affects the learning process and student outcomes, recently published studies report that searching for relevant learning content is a difficult and time-consuming process [7,8]. ARETE project aims to support AR teaching and training applications by contributing to the developing and evaluation of Mirage·XR platform: an authoring toolkit for creating Extended Reality (XR) learning content, compliant with the IEEE standard for Augmented Reality Learning Experience Model (ARLEM) [9–11]. Mirage·XR will be incorporated within ARETE's digital repository to establish the communication between the authoring tool and the Moodle server, so that content creators can store their resources to it or reuse relevant material.

This paper aims to present the effort to exploit and enrich previous works to develop two plugins that will suit the needs of the ARETE project and will be able to support the discovery of the resources included in its digital repository by creating LOM-based metadata and making them available for harvest via well-known protocols that allow interoperability. To link up content originating from various digital repositories in such a way that a global search for learning resources is feasible, the integration of IEEE-1484.12.1-2020 standard for Learning Object Metadata (IEEE-LOM) [12] and Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) [13] within ARETE's Moodle repository is considered a feasible harvesting solution for a federated network of ARLEM and other educational content repositories.

First, the paper will present the standards that are applicable to ARETE's repository and are related to the dissemination of its educational resources. Then, the paper presents ARETE's digital repository and indicatively presents some of the LOs included in it. Next, the two Moodle plugins that were considered to be able to facilitate the process of semi-automated generation of IEEE-LOM and Dublin Core (DC) metadata [14] as well as their exposure through the OAI-PMH protocol will be demonstrated. Finally, conclusions and future work follow.

2 Applicable Standards

ARETE project aims on the development and evaluation of an AR authoring toolkit for the creation of 3D interactive learning content based on related standards. The project promises to create AR/3D data infrastructures for educational purposes using compliant standards to preserve: applicability; reproducibility; interoperability; accessibility; and sustainability. To evaluate the effectiveness of AR in learning, the project's ecosystem will be piloted in three different studies [15].

In the light of LOs' reusability and interoperability, a formal way of describing learning resources is essential. There is a need for a conceptual model which will include the most important fields, capable of representing the different aspects of a learning resource. LOM is a widely used data model for the description of LOs and similar digital resources [16].

In IEEE-LOM a LO is defined as *"any entity, digital or non-digital, that is used for learning, education, or training"*. The conceptual schema of the standard describes the structure of a metadata instance for a LO, while taking into account the diversity of cultural and lingual contexts in which the LOs and their metadata will be exploited. A metadata instance can be used by a learning technology system to manage, locate, evaluate, or exchange LOs. LOM data model defines 9 categories on which LOs' characteristics can be grouped (see Fig. 1). Each category contains attribute-elements which are used to provide relevant information about the educational resource [12].

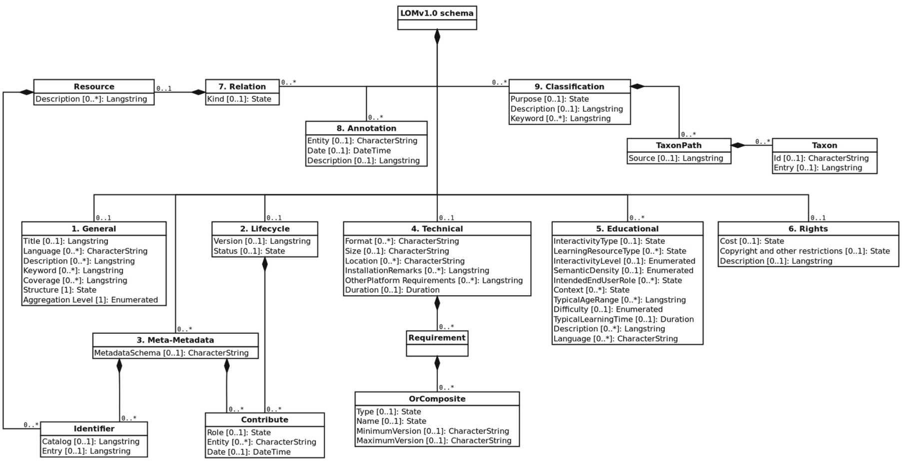

Fig. 1. Hierarchy of elements in the LOM data model. Copied from [16].

As storage becomes cheaper, more and more resources are stored in repositories, making search for them more difficult. One way to facilitate object discovery is to create a union list (aggregations of metadata) thus stakeholders can then search locally. The content of Learning Object Repositories (LORs) is indexed so that stakeholders can search and retrieve LOs that suit their needs. OAI-PMH is a low-barrier mechanism for repository interoperability and provides a way to create said union list.

Within the OAI-PMH, metadata records are encoded in Extensible Markup Language (XML) format and harvested using Hypertext Transfer Protocol (HTTP) requests [17]. The standard provides an application-independent interoperability framework based on metadata harvesting and includes a set of six services, called verbs [13]:

- **Identify:** used to retrieve information about the repository;
- **List Identifiers:** used to retrieve record headers from the repository;
- **List Metadata Formats:** used to harvest full records from the repository;
- **Get record:** used to retrieve an individual record from the repository;
- **List Sets:** used to retrieve the set structure of the repository; and
- **List Records:** lists available metadata formats that the repository can disseminate.

OAI-PMH protocol supports multiple formats of metadata but at a minimum repositories must be able to return records with metadata expressed in DC without any qualification [13]. The first IEEE metadata standard for LOs, IEEE 1484.12.1-2002 (IEEE-LOM, 2002), was established as an extension of DC, thus each resource can be described using the LOM's metadata elements [18]. In the OAI-PMH integration to the ARETE Moodle repository the metadata was expressed in both Simple-DC and IEEE-LOM manifestations.

In line with ARETE's objectives, Mirage·XR platform will be used as an authoring toolkit for the creation of XR learning content, compliant with the IEEE-ARLEM standard, meeting the criteria of interoperability and sharing. Mirage·XR is a reference implementation of an XR training system that enables users to share experiences via XR and wearables [9]. The platform was used for the development of ARLEM to demonstrate how training applications can be created using an AR editor for learning experiences [11].

ARLEM is a recent standard developed to support the implementation of AR training systems by providing a comprehensive conceptual model and the corresponding data specifications for the representation of activities, learning context and environment for AR-enhanced learning. Moreover, it can support interoperability for content used in "mixed" reality experiences that combine real-world guidance with traditional learning material such as video or existing web applications. The standards supports reuse and repurposing of existing learning content thus facilitating the creation of both experience repositories and online marketplaces for AR learning content [19].

3 ARETE's Digital Repository

According to the project objectives, ARETE H2020 aims to enable the disruptive innovation of AR for interactions, access and distribution of AR content through three different pilots [15]. The project will share with European students and citizens who participate in the project high quality contents about the application of AR within the three pilots by providing access to a repository which will include: data gathered at schools through the ARETE application; a collection of good practices gathered during the project, released as Open Educational Resources (OER); and a reasoned collection of AR and other contents utilised within each pilot study.

The digital repository of the ARETE is the online archive where digital assets can be stored for short and longer term. The repository activities have been split into two tasks separating out the storage of AR learning content into a content repository (realised as Moodle plugin) from the activity log repository that stores behavioural traces of the users (realised as learning record store). Posting the AR content within a pedagogical environment is paramount to provide insight to the researchers and the public on how the Mirage·XR platform can be incorporated within a Learning Management System (LMS). Although a number of digital repositories are available for storing digital media formats, not many can include AR scenes with an educational context. After reviewing the state of the art digital repositories, Moodle was selected for storing the project's learning content due to it is an open source option around the world and it has a strong community and pedagogical design.

The incorporation of the Mirage·XR platform within ARETE Moodle digital repository will be achieved with an AR Experience plugin (mod_arete), capable to establish the communication between the authoring tool (Mirage·XR 'edit mode') and the Moodle server. The plugin allows teachers and admins to see a list of available uploaded learning activities as well as to delete or edit their own activities. IEEE-LOM and OAI-PMH can be the solution for linking different digital repositories in a way that allows a global search of material, thus facilitating the creation of a federal ARLEM network and other educational repositories.

3.1 Learning Objects

As part of the ARETE project plan a good number of AR and other learning assets will be utilised within each pilot study. The project aimed on a structured subdivision of the educational resources in reusable LOs, considering their size and granularity level to their reusability potential. The LOs included in each pilot study will be accommodated in the ARETE Moodle learning repository, accompanied by LOM metadata to facilitate their discoverability. So far, a reasoned number of LOs has been identified for the assets included in Pilot 1 and Pilot 2 studies.

Pilot 1 study aims to support students on literacy tasks by utilizing an AR learning application which provides a variety of learning resources of increasing difficulty. An indicative work of the LOs which were defined by breaking down the assets that are included in the said application are:

- *Vowel chart:* A set of 40 interactive AR digital files containing letters, audio sounds, icons and AR/3D animated models which represent all the vowels in

the English language. The recommended educational use of the vowel chart is the utilization of AR technology for teaching and learning to Hear, Read and Spell the vowel sounds in the English Language.
- *Reading and spelling rules:* A collection of 7 augmented reading and spelling rules essential to explain irregularities in English language is presented in detail with interactive exercises and short videos. Some of the rules are original and were developed to be retrofitted into the English language thus to explain many of the anomalies. Others are widely known, but most contain some novel variations.
- *Flashcards:* A collection of 10 flashcards used to imprint the images of English prefixes and suffixes. The utilization of this collection can facilitate the learning of troublesome prefixes, suffixes and common word endings in the English language. The collection consists of digital 3D objects with AR animations embedded within.

Pilot 2 concerns the facilitation of AR in Science, Technology, Engineering, and Mathematics (STEM) activities and aims to support students with two independent multilingual applications: one for Geometry; and one for Geography learning. The applications contain a plethora of assets that can be autonomously used to support different learning objectives. For the purposes of the ARETE project, these assets were subdivided into the following LOs:

- *Geometry Workbook:* A tangible Geometry workbook for primary school students. The workbook is a technology-powered AR kit that aims to provide an easy and fast way to explain and visualise 3D shapes, cross section and complex geometrical shapes. It can stand alone as a LO but in order for the user to take full advantage of the AR features the installation of the AR Geometry application is required.
- *Geometry building blocks:* A collection of geometric building blocks that represents the geometry shapes of circle, hexagon, rectangle, square and triangle geometry shapes. The objects are provided in both tangible (printable) and digital format and can be used to bring geometry shapes to life and help students visualize and understand their properties better. This LO can additionally be used along with the AR Geometry application to enhance learning and teaching.
- *3D/AR shapes:* 5 collections of 3D/AR assets corresponding to geometric shapes. Each of these collections includes a group of 3D representations of a relevant 2D geometric shape. For example the LO of the circle includes 3D representations of the shapes torus, cone, cylinder, sphere and hemisphere. The LOs included in these collections provide teachers and learners an innovative and exciting way of learning geometry through visualization and interaction.
- *Geography map:* A physical map of the world that can be used autonomously in Geography learning activities. However, the use of this map aimed to be suited with the ARETE's Geography application to provide opportunities for interaction and play.

- *Geography workbook:* A workbook that provides an introduction to several Geography and Social Studies topics about the continents. Lessons throughout the workbook are reinforced with maps, exercises, puzzles and review questions. The workbook can be used along with the ARETE Geography application, thus providing AR functionality to the included activities and visualizations.
- *Geographical and Social Science components:* 5 collections of Geographical and Social Science 3D/AR digital assets: animals; plants; volcanoes; bases; and heritage of the world. Teachers and students can use these LOs to teach or learn though visualizations on those topics using AR technology.
- *Continents:* 7 collections of 3D/AR components that represent the continents of the world. Each of these collections can be used by teachers and students who wish to emphasize in specific continents and learn/teach though visualizations about the geographical and social science elements associated with it.

4 LOM and OAI-PMH Moodle Integration Plugins

Although several initiatives in the past have dealt with LOs and their reusability and interoperability have failed due to the limited demand of the community resulting from a lack of a middleware application to facilitate the movement of the LOs' usability from the LMSs. Within ARETE project a plugin called "moodle-mod_arete", hereafter referred to as the "ARLEM", has been implemented with the aim of developing an interactive AR content toolkit [15]. The plugin implements a service back-end to store and retrieve ARLEM compliant activity units, thus offering users the ability to provide AR experiences for students as learning activities in Moodle courses [20]. Within this project the interoperability of XR objects is not referred to the exchange between LMSs, but the upload and shared content through Mirage·XR and ARETE Marketplace.

Metadata refers to information that provides meaning and context to other collected data and consists of tags generated by a combination of computers and humans. Considering that LORs can make their content more accessible through the availability of shared information about resources, two plugins where developed: the "LOM-Moodle"; and the "OAI-PMH-Moodle". The first one aims to facilitate the processes of creating LOM-based metadata for the description of the ARETE's LOs while the second one was developed to enhance the discoverability of resources by exposing and making public their metadata via the OAI-PMH framework. It is worth to be noted that both plugins have not yet been finalized and the description provided in this article refers to their current version. The two plugins are linked with each other in a way that "OAI-PMH-Moodle" plugin requires the installation of "LOM-Moodle" plugin. Both of them are based on previous work that target on LOM metadata editing, generation and exposure via the OAI-PMH protocol.

Figure 2 presents a draft architecture of the plugins installed in the ARETE's Moodle repository concerning those that handle/create data and metadata for an AR activity and its exposure via OAI-PMH. LOM-Moodle plugin aids on metadata editing and the automatic generation of LOM/XML files, capable to describe AR experiences and other types of modules. The LOM and OAI-PMH integration plugins give the opportunity to users (teacher or administrator), after initiating a course, an activity or a resource, to edit the respective metadata descriptor file and then to export it via the OAI-PMH protocol.

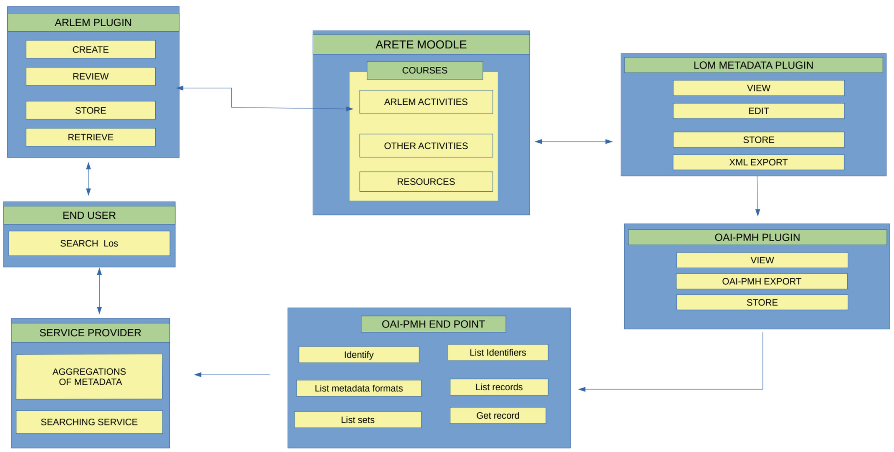

Fig. 2. Draft architecture of ARETE's Moodle plugins.

4.1 Previous Work

The description and availability of LOs to other stakeholders using the IEEE-LOM and the OAI-PMH framework is not a new approach. Such work has begun to arise in 2002 when IEEE released the 1484.12.1-2002 standard [18]. The same year OAI published the OAI-PMH v.2 production release. So far, there are approximately 2000 plugins in the Moodle plugins directory [21], however there is no much work yet on facilitating the above standards in the context of Moodle. In a search for Moodle plugins that can serve the description of LOs using the OAI-PMH and LOM standards, only few relevant results appeared.

Moodle provides the "ODS OAI-PMH" plugin that serves as Data Provider for OAI-PMH 2.0 Harvester which supports all Moodle 2.x default modules, but also tries to support other unknown modules. The initial work for this plugin goes back to 2015 when Open Discovery Space (ODS) released an accordance article to describe their work on *"Searching and exposing learning objects from Moodle: The ODS experience"* [21]. Their purpose was to facilitate search of LOs by providing teachers with mechanisms for automatic generation of LOM-based metadata for harvesting using the OAI-PMH framework. Thus, they developed two Moodle plugins: the first one targets on providing teachers with easy search access to ODS LOR; and the second one supports teachers and administrators to easily expose the content. Among others, ODS in that article acknowledge the need for future work on automatically generated metadata for LOs that is provided to OAI-PMH harvesters.

In 2018, a work on enhancing the process of automatically generated LOM-based metadata for open educational resources, able to be harvested by using OAI-PMH, was released for the needs of the "Humboldt-Universität zu Berlin's" Moodle repository. The work that serves this scope concerned the development of two Moodle local plugins: the "moodle-local_metadata"; and the "moodle-local_lom". The "moodle-local_metadata" is a modification of Moodle's "local metadata" plugin allowing it to communicate with the "moodle-local_lom" [22]. It supports extra metadata to be defined and assigned to the context level 'course' in Moodle, so that a course's LOM-based metadata can be exposed via the OAI-PMH interface [22]. The "moodle-local_lom" plugin was developed aiming on generating LOM-based metadata for Moodle courses [23]. It provides a Moodle repository the capability to act as a data provider using the included OAI-PMH interface [23].

The two plugins which were developed to support "Humboldt-Universität zu Berlin's" Moodle repository were tested for compatibility with the ARETE repository and can be used to serve most of the ARETE's repository functionality. According to the ARETE project needs, the plugins used to support the description of LOs and their metadata exposure should not only be able to serve the Moodle courses but to additionally provide such functionality for the Moodle modules. Therefore, the "moodle-local_metadata" and "moodle-local_lom" plugins were enriched with code that facilitates generation and exposure of LOM metadata for Moodle's courses and modules, including various types of learning resources and activities. Moreover, the plugins where enriched to include ARLEM activities and they so far support the creation and sharing of metadata for courses in general and the following Moodle modules: "resource"; "book"; "lesson"; "workshop"; "url"; "page"; "quiz"; "h5activity"; "wiki"; and "arete". The "arete" type is used for ARLEM experiences.

4.2 LOM Integration into Moodle

A teacher, among others, using Moodle can create a course or add some modules to it. During the initiation of a course or module, the user is asked to fill in a form with details about the corresponding resource such as its title, some description and keywords. These details are stored in the Moodle file system. The role of the "LOM-Moodle" plugin is to add additional LOM-based fields so that content creators can describe in a more comprehensive way their learning resources.

The contribution to the initial "moodle-local_metadata" plugin concerns the initiation of several already existing fields with corresponding default values to assist teachers on metadata editing. Moreover, in "LOM-Moodle" plugin the LOM element of "interactivity level" was added and the "contribution" field was duplicated so that more than one contributors can be defined. Additionally, "moodle-local_metadata" was enhanced to offer metadata viewing and editing options for Moodle modules (resources/activities), instead of only providing such functionality for courses.

In addition to the initial details that a user may provide during the creation of a module or course, the metadata editing form provides default values for the following LOM fields: general (identifier, language and aggregation level); lifecycle (contribute role and date); technical (format, size, location and requirements); educational (intended end user); and rights (cost, copyrights and license). The annotation field was decided not to be included due to the fact that metadata editors can provide such details on the educational description element. Additionally, the LOM classification and relation fields have not yet been finalised and thus are not provided.

ARETE project aims to release, in the form of OER, the collection of good practices gathered during the project by using: an open license for the contents produced (such as Creative Commons); file formats that are usable by most of the devices on the market; and the structured subdivision of the materials in reusable modules. Some of the default metadata values used by the plugin were defined based on the ARETE project thus making easier metadata editing to teacher participants, while others are generated based on the technical characteristics of the repository.

Once the "LOM-Moodle" plugin is installed, the admin can start setting up the metadata fields they wish to include for the description of courses and modules. To do that, they can go to Moodle's local plugins and then set the metadata fields via the *"Course metadata"* or *"Module metadata"* provided options. The plugin provides the options to: create a new profile field (e.g. check box, date/time, text area); to create a new profile category; to use already initiated LOM fields; or to delete the initiated LOM fields. By choosing the LOM initiation option, a set of LOM fields are auto-generated. However, just like the original "moodle-local metadata", the "LOM-Moodle" plugin offers the capability of adding more fields by choosing "Create a new profile field:" and then specifying its category [24]. Furthermore, the plugin offers the options of editing, deleting or reordering the initiated fields and their elements.

After the admin has initiated the LOM fields for the contexts of courses and modules, authorised users can start adding metadata to their content. During the addition of a course or module to Moodle, both teachers and admins can view and edit the metadata provided by the "LOM-Moodle" plugin using the options of "Module metadata" or "Course metadata". When the users select one of these options, they are transferred to a page where the initiated LOM-based metadata form appears (see Fig. 3). Users can view the auto-generated values in the form, can edit the form based on their preferable values and finally save theirs changes into the Moodle file system. In order for future stakeholders to have the option to overview the saved LOM metadata representation to decide whether the LO suits their needs, there is a need of disseminating the file.

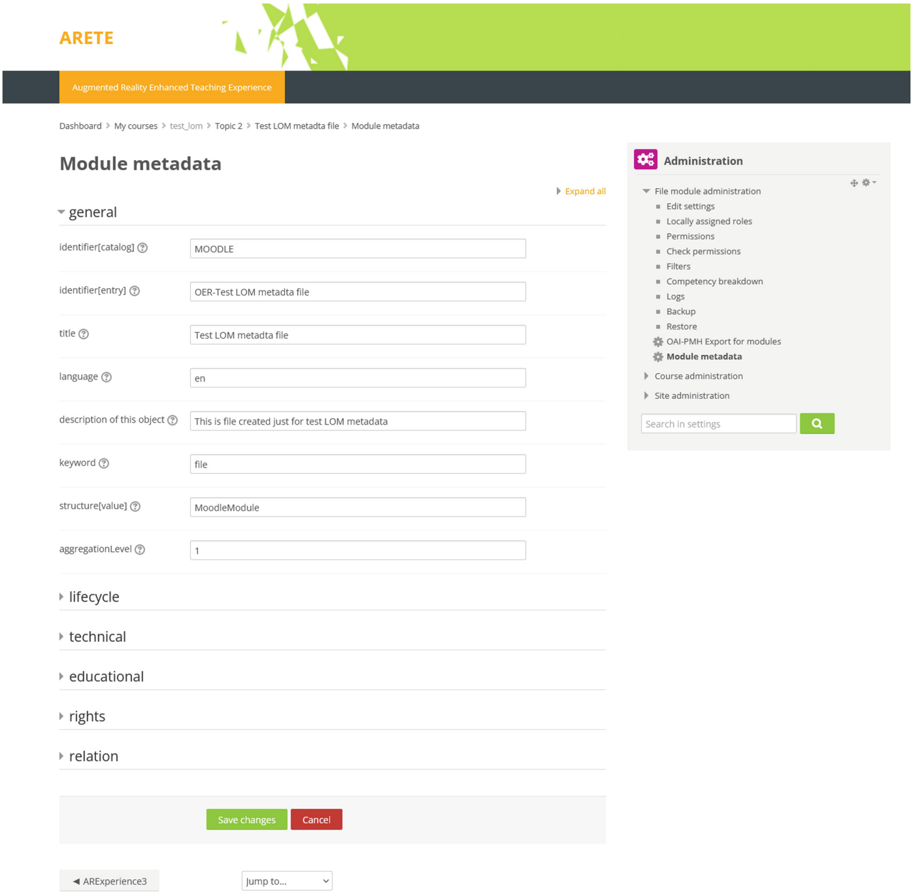

Fig. 3. LOM metadata editing for Moodle modules.

4.3 OAI-PMH Integration into Moodle

The OAI-PMH interface provided by the original "moodle-local_lom" plugin will be used with some modifications to disseminate the generated LOM/XML files. The contribution to this plugin is to modify it to serve the module context in addition to the course functionality and particularly to include the module activity type for AR experiences.

The dissemination of LOM metadata file is exclusively depended on whether or not the teacher/administrator of the learning resource wishes to proceed on generating its XML metadata file. The developed plugin, hereafter referred to as "OAI-PMH-Moodle", adds to the Moodle's course/module view page the option "OAI-PMH export", located in the Action menu on top of the metadata editing option. By the time that a user clicks on this button a new page appears asking the user if they wish to create a LOM metadata file for this course/module.

The message also informs the user that the file being generated will be disseminated and asks if they wish to proceed. If the user chooses to continue, then a LOM/XML file is automatically generated, including the values provided in the LOM form and saved in Moodle filesystem. Once the XML file is generated, the corresponding course/module will be included in the OAI-PMH interface's data provider list and can will be able to be exposed via the OAI-PMH harvester. After this process, users may choose to make further modifications to their course/module metadata, but the XML file must be recreated to include the modified metadata information.

The "OAI-PMH-Moodle" plugin handles the metadata provided by the LOM-XML file to provide the OAI-PMH functions through a target end-point (see Fig. 4). OAI-PMH framework provides the six services used to retrieve information regarding: the repository; the record headers; the full records; a specific record based on its identifier; a list with the available metadata formats; and lastly the set structure of the repository. Service providers can build their own harvester and target the OAI-PMH endpoint to collect information about a repository and its resources via HTTP requests. By making such requests, service providers can create a collection of metadata records originating from various heterogeneous learning systems. ARETE Moodle repository with the help of the "OAI-PMH-Moodle" plugin can work as a data provider and respond to service providers' requests with a copy of its metadata records (see Fig. 5).

Considering the type of learning resources aimed to be provided by ARETE's Moodle repository, the OAI-PMH functions were modified to further support the type of AR activities created through the MirageXR authoring toolkit. Additionally, to facilitate service providers in retrieving filtered metadata records of the ARETE's learning content, modification actions were taken in the set structure defined in the OAI-PMH implementation. Specifically, three categories of learning resources were considered to represent the content of ARETE repository: "moodle-course", "moodle-module" and "ARLEMs". The ARLEMs set consists of AR learning experiences created through the ARETE's authoring toolkit. By defining these sets, future service providers can target specific resources. For example, they could collect records only for ARLEM activities by sending an HTTP request with the corresponding parameters: the verb "list records"; and the "ARLEMs" set. Finally, to support retrieval of metadata records, descriptor files are offered in both LOM and DC formats. By using "LOM" or "DC" as the metadata prefix parameter, providers can only collect the metadata records whose format is compatible with their infrastructure.

Simple interface to sample server

This is an implementation of an OAI-PMH 2.0 Data Provider, written in PHP

- Identify
- ListMetadataFormats
- ListSets
- ListIdentifiers(metadataPrefix=lom)
- ListRecords(metadataPrefix=lom)
- GetRecord(metadataPrefix=lom, identifier=OER-zl_testcourse_1)

Fig. 4. OAI-PMH end point for harvesting.


```
−<OAI-PMH xsi:schemaLocation="http://www.openarchives.org/OAI/2.0/ http://www.openarchives.org/OAI/2.0/OAI-PMH.xsd">
  <responseDate>2021-10-23T13:18:45Z</responseDate>
  <request verb="GetRecord" metadataPrefix="lom" identifier="OER-Test LOM metadta file_115">arete.ucd.ie</request>
 −<GetRecord>
   −<record>
     −<header>
        <identifier>OER-Test LOM metadta file_115</identifier>
        <datestamp>2021-10-23T15:45:00Z</datestamp>
        <setSpec>moodle-module</setSpec>
      </header>
     −<metadata>
       −<lom xsi:schemaLocation="http://ltsc.ieee.org/xsd/LOM http://ltsc.ieee.org/xsd/lomv1.0/lom.xsd">
         −<general>
           −<identifier>
              <catalog>MOODLE</catalog>
              <entry>OER-Test LOM metadta file</entry>
            </identifier>
           −<title>
              <string language="en">Test LOM metadta file</string>
            </title>
            <language>en</language>
           −<description>
              <string language="en">This is file created just for test LOM metadata</string>
            </description>
            <keyword> <string language="en">file</string></keyword>
           −<structure>
              <source>LOMv1.0</source>
              <value>MoodleModule</value>
            </structure>
            <aggregationLevel>1</aggregationLevel>
          </general>
         +<lifecycle>
         +<technical>
         +<educational>
         +<rights>
        </lom>
      </metadata>
    </record>
  </GetRecord>
</OAI-PMH>
```


Fig. 5. Returned LOM metadata record via OAI-PMH protocol.

5 Conclusions and Future Work

The proposed solution aims to provide ways to support the description of digital LOs and improve their discovery in search engines. The educational aspects of a LO can be more than well described by implementing the IEEE-LOM standard which provides a generic metadata schema thus supporting various types of resources. This article presented the implementation of "LOM-Moodle" and the "OAI-PMH-Moodle" plugins as a feasible solution for creating and sharing LOM-based metadata. It is worth to be mentioned that the plugins are still under development and should be tested for further Moodle versions to allow project partners to use them regardless of the Moodle version they have. Furthermore, although IEEE-LOM was considered suitable for describing XR LOs, the authors believe that several extensions of LOM specifically targeting XR learning will appear in the future. Accordingly, the plugins presented in this article are planned to be enriched in the future to address more aspects focusing on XR learning, such as the ethical considerations of a LO and the type of inputs/outputs (haptic, audio, etc.).

OAI-PMH service providers can help students and other stakeholders find appropriate learning resources by collecting LOM-based metadata from various repositories and by building search mechanisms on top of them. Despite that OAI-PMH facilitates the sharing of metadata files based on a common format, it is still under consideration whether the corresponding plugin will be used by ARETE's Moodle digital repository, due to the limited number of search service providers and the lack of infrastructures appeared to be focused on LOs. The research on discovering service providers that could support searching procedures on ARETE's digital repository revealed that there are not many volunteers. Only few providers considered to collaborate with the project and those who did had a different approach to using LOM-based metadata. Therefore, further research is worth to be done in this domain to assure that project's LOs will be able to be easily discovered and shared by other stakeholders. As an alternative to the OAI-PMH service providers, the development of a global marketplace is currently being considered by the project coordinators.

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A Case Study of Teachers' First Designs Using ASYMPTOTE: A Tool for Teaching and Learning Mathematics Online

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Abstract. In this paper, we present the ASYMPTOTE system - a result of a European project arising from the needs that emerged during the covid-19 pandemic in teaching and learning mathematics online. The components of the system (web portal and smartphone application) are presented with a particular focus on ASYMPTOTE's task and learning graph functions. Training courses on the ASYMPTOTE system were held for in-service and future mathematics teachers from Greece and Italy. With the aim of investigating how the participants of these courses used the system in the creation process of a learning graph for a specific mathematics' topic, we examined two case studies. The findings show that the ASYMPTOTE system is an effective platform for the creation of interactive math tasks and LGs.

Keywords: ASYMPTOTE system · Learning Graph · Online mathematics teaching and learning

1 Introduction and State of the Art

The covid-19 pandemic brought major challenges to the educational system (Barlovits et al. 2021; Mishra et al. 2020; Zhang et al. 2020). Both teachers and students had to adapt to a new reality since teaching and learning were conducted, for a long period of time, mostly remotely, synchronously and/or asynchronously (Barlovits et al. 2021; Mishra et al. 2020; Zhang et al. 2020). In Mathematics education, where the integration of technological means in the teaching process had been more conservative in the previous years (Chronaki and Matos 2014), the need to develop new learning environments that guide the learner remotely was evident (Flores and Swennen 2020; Hall et al. 2020).

The new reality and the problems that the covid-19 pandemic arose inspired the creation of the ASYMPTOTE Strategic Partnership in the Field of Higher Education project, funded by ERASMUS + KA2. ASYMPTOTE is an acronym for Adaptive Synchronous Mathematics Learning Paths for Online Teaching in Europe. The project is carried out by seven institutions from five European countries (Germany, Greece,

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Italy, Portugal and Spain) and aims to develop an adaptive, synchronous, mobile system for online mathematics education. The technical starting point of ASYMPTOTE was the MathCityMap system (Cahyono and Ludwig 2018), that concerns the design and implementation of outdoor learning trails.

ASYMPTOTE consists of a web portal and a mobile app. Through the web portal teachers can search for, and select existing tasks, or create their own in order to design a task sequence with multiple levels of difficulty, for a specific topic of Mathematics i.e. a Learning Graph (LG). Concurrently, the students through the app are able to see the available tasks that the teacher has set for them and go through them, having systematic, synchronous feedback on their entered solutions. Meanwhile, the applied reward-based system facilitates students' engagement, and puts the app in the gamification spectrum of education.

Moreover, ASYMPTOTE provides a Digital Classroom mode that offers the possibility of direct communication between the teacher and the students and between groups of students assigned by the teacher. The Digital Classroom offers an individual progress display and a class overview that declare it a useful assessment tool. These possibilities allow teachers to provide individualized support to the student in the sense of formative assessment (Black and Wiliam 2003), rendering the design process easier as they can design learning graphs, with tasks adapted to each student's individual learning progress.

Lastly, to facilitate learning for students with disabilities, a read-out-loud mode and a zoom function are available. Also, all the created tasks in the system are translatable in various languages which helps bridge language barriers, by facilitating teachers from around the globe to translate and use tasks into their language, and by enabling foreign students who are still learning the language to solve tasks in their mother tongue.

ASYMPTOTE's features can be utilized in almost any teaching and learning setting that encompasses technology. From face to face Technology Enhanced Learning to blended and online learning, ASYMPTOTE can be an asset for both teachers and students. The system can be placed in the general framework of Garrison's Community of Inquiry (2017). This model envisages a number of collaborative interactions that contribute to generating a remote presence that fosters the development of such a community. The teacher plays the role of mediator and facilitator in the creation of such community (Garrison 2017). Indeed, teachers are called upon to create the organizational and didactical conditions for quality collaboration between learners to take place. Therefore, especially in an online learning environment where learners can be easily distracted, become passive or feel isolated and disconnected from their peers and the teacher, it is important to establish connections that are able to create and maintain an active, interactive, collaborative and engaging online learning environment. With ASYMPTOTE students can construct meaning through their interactions with the content (cognitive presence) and identify with the community by communicating and interacting in the Digital Classroom environment (social presence). Meanwhile the teacher is able to design, re-design and adapt the tasks and the learning graphs according to the learner's needs, creating worthwhile learning outcomes (teaching presence).

Although the CoI framework is a well known pedagogical model, in the literature there is a lack of studies regarding its use in Mathematics education (Calder et al.

2018). The training of teachers to use ASYMPTOTE in the context of the CoI theoretical framework is considered important for the system utilization in authentic education circumstances. A thoroughly designed professional development program was implemented for mathematics teachers in the context of ASYMPTOTE project. Specifically in this paper after reviewing ASYMPTOTE's task and learning graph functions we will examine two case studies (2 LGs) that were created by mathematics in-service and future teachers, during the long term training courses that were held in Greece and Italy.

2 The ASYMPTOTE System

2.1 Tasks

In Mathematics education designing, selecting, modifying, using, sequencing, observing, and evaluating tasks takes a big part in the teaching and learning process (Margolinas 2013). Task design lies at the center of Mathematics methodology and pedagogy (Artigue and Perrin-Glorian 1991), because being engaged in a task brings learners across Mathematics concepts, ideas, strategies and helps them develop Mathematical thinking (Margolinas 2013). ASYMPTOTE provides a repository of tasks for primary, secondary and university level Mathematics. As it has been mentioned above, through the web portal teachers can search for and select existing tasks or create their own.

Tasks in ASYMPTOTE are divided into 4 broad categories regarding their focus: (a) learning tasks that include simple Mathematics and/or Mathematical knowledge (b) training tasks that include Mathematics and/or Mathematical techniques, (c) reasoning tasks that require the student to use a Mathematical argument, interpretation, or explanation, and (d) modelling tasks that have a strong connection to the real world. This connection can range from easy standard modelling up to real world problem solving. Modelling tasks usually include a picture for identification in the corpus of the task. This picture has to be an obvious connection to reality (Barlovits et al. 2022).

Tasks in ASYMPTOTE are created from a predefined task template, facilitating the ability to address as many different problems and topics as possible throughout all classes and skill levels. This template consists of (a) basic information about the task such as its title and description, its author's information etc., (b) core components such as the task type and solution format, and (c) metadata such as its assigned grade and tags.

A very important factor for task creation when using technologies is the answer types that the system can support. It is one of the main elements that sets the limitations and the prospects for the creators. In ASYMPTOTE the answer format is the core of each task because it determines the answer behavior in the app. ASYMPTOTE currently provides eight different answer formats:

- Exact value
- Interval: especially useful when the answer cannot accurately be calculated e.g., for more complex modelling tasks
- Multiple-choice: this category also includes the answer type of true or false.
- Fill in the blanks: The basic requirement when designing a task with this answer type is that the student should have no difficulty in understanding the data and the question asked despite the blanks.

- Vector (exact value): Useful in finding the coordinates of a point
- Vector (interval): Used when the coordinates cannot be accurately calculated
- Set: The solution set can contain several elements. A typical example is an equation that has many solutions.
- Fractions
- Matrices.

Supporting a self-guided working process, each task can and should contain a well-explained sample solution that not only displays the correct result but also describes all steps in between. The sample solution should be detailed enough that students are not only able to compare their own answer but also understand the thought process that led to it. A sample solution might contain text, image, and video files that can be viewed by the students after completing or failing the task. In line with the importance of immediate elaborate feedback (Gurjanow et al. 2019, Van der Kleij et al. 2012), instant validation by the app and automatic feedback depending on the given answer format is available. Moreover, tasks can be equipped with a maximum of three stepped hints, ideally leading the students along the solution process. An example of a suitable succession of stepped hints could be (a) a different, more implying wording of the question, then (b) an indication towards one possible formula and (c) providing the formula itself. Hints can include text, images and videos. This follows the ideas of Beal et al. (2007) and Kochmar et al. (2020) in assisting multimedia material to foster the student's learning progress.

Another feature that the system provides, and is required in the task form, is task Metadata. Every task can be described by Mathematical tags so that both teachers and learners can easily identify and select them. Simultaneously, each task is also addressed to a stage of thematical hierarchy. The ASYMPTOTE curriculum was created after analyzing, comparing, and combining the constituted curriculums for Mathematics in Italy, Germany, Greece, Portugal, and Spain, and defines the hierarchy of the tasks. The tasks are divided into 5 main categories: primary, lower secondary, upper secondary, and university. Each level consists of specific mathematical subjects that are developmentally appropriate. The Mathematical subjects that are involved in each task, define their place in the hierarchy.

To further help teachers assess whether a task is relevant and suitable for their students and/or the mathematical topic they are currently teaching, several smaller assistive features are in place. A voting system allows users to recommend a task they experienced to be useful. This voting will lead to a ranking for tasks of every topic instantly displaying the most frequently used ones. Inspecting a task also provides information about how often it has been used as support, challenge, or main task, as well as, how often it has been used in total. Moreover, a list with all public learning graphs that this task has been used in, offers best-practice examples and inspiration for the teachers-creators. All these features together should grant a quick and proper insight about the quality and usefulness of a task.

Finally, the system in its final version will provide the loop task type (not yet supported). Loop tasks will be a collection of permutations of the same task that allow students to train their skills on a certain topic/task via repetition (Barlovits et al. 2022). In a loop task, for example, the teacher will be asked to define the equation $ax + b = c$, specify the number for a, b, c, and x and choose the number of tasks that he wants the system to automatically generate. A mode to manually create multiple permutations of a text-based task will be supported as well, in the final version of the system (Barlovits et al. 2022).

2.2 The Learning Graph

In ASYMPTOTE, tasks are not presumed only as single events. The focus is concentrated on sequencing them to produce a complete learning trajectory for a specific Mathematics topic. A learning trajectory is defined as a sequence of pre-selected tasks that are based on didactical considerations of a student's learning process and focus on its evaluation (Simon 1995). The tasks that the teacher selects for a particular learning trajectory are designated to assist the students in improving their knowledge or skill in a particular subject area (Brusilovsky 1992; Yang and Lau 2010).

In a task sequence like this, prior or first tasks should provide experiences that scaffold the solution of subsequent tasks, thus giving opportunities to the learner to engage in more sophisticated Mathematics and grasp more abstract concepts (Margolinas 2013). A task sequence is important to transform knowledge from implicit, in-action, to a format that is formulated, formalized, memorized and culture related (Margolinas 2013). As Margolinas (2013, p. 11) states "a task sequence starts with situated problems, (…) to evoke informal strategies and representations, and continues by changing the focus to formalizing and generalizing solution procedures (…)".

In a sequence, earlier tasks might be of a more technical nature, providing learners with the tools and techniques that they will need to use in order to undertake subsequent tasks with situational understanding. Earlier tasks might include images, graphs, equations, or technical components that lie in the base of the subject's knowledge. Margolinas (2013) defines 3 types of sequences in Mathematics education: i) the first type maintains the problem formulation throughout the sequence while the numbers selected for each task increase the complexity gradually, ii) another type of sequence is one where the problem is presented progressively more complex, by the addition of steps or variables, iii) finally, the third type is related to the topic of Mathematics that is under examination.

In ASYMPTOTE task sequences are presented in the form of a Learning Graph (LG). This format includes 3 main categories of tasks: main tasks, support tasks and challenge tasks. The LG is represented visually by a fishbone diagram (Fig. 1) which consists of a central spine, where the main tasks lie and branches that connect it with the subtasks (challenge - left side, support - right side) (Barlovits et al. 2022).

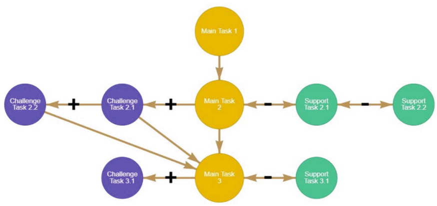

Fig. 1. The fishbone structure of ASYMPTOTE's LG

In more detail, the main tasks are mandatory and are located on the main spine of the LG. Each main task should ideally cover an aspect of the mathematics topic in consideration, so that when a student solves all main tasks could have learned or encountered the basic ideas of the LG's topic (Barlovits et al. 2022). The support tasks are located at the right side of the main task and provide students with an easier version of the task or a task that lies in the base of the subject's knowledge and can support students to solve the corresponding main task. More than one support task can be assigned to the same main task (Barlovits et al. 2022). Finally, the challenge tasks are located on the left side of the main task and are more difficult in order to challenge or deepen the understanding of the students who have successfully solved the main task. Challenge tasks are only visible to those who have already solved the associated main task or another challenge task (Barlovits et al. 2022).

In a LG either than the main tasks which are mandatory, the students have the option to choose whether or not to solve the available support and challenge tasks. This factor makes the learning process autonomous and self-guided (Deci and Ryan 2008) allowing each student to form a personal way through the same LG, depending on their own performance level (Barlovits et al. 2022). Moreover, the system's gamification, where students receive points for a successful task solving process (Van der Kleij 2012, Lieberoth 2015), can motivate students and foster learning. Students are able to see the already achieved points and their progress through the LG. They can revisit unlocked tasks that are not yet completed, and they can restart the LG in its entirety with the ability to skip tasks that have been solved previously (Barlovits et al. 2022).

3 Research Question

The research question guiding our study is defined as follows: How did the teachers and future teachers that participated in Italy's and Greece's LTC, utilize the ASYMPTOTE system's features in the creation process of a LG for a specific mathematics' topic?

4 Methodology and Data Source

Between April and June 2022, in accordance with the intellectual outputs of the ASYMPTOTE project, training courses for mathematics in-service and future teachers (from here on, we will refer to these two categories as "(future) teachers") were started in some of the partner countries. These courses are called Long-Term Curriculum (LTC) and all have the same structure, which we describe below. The LTC is composed of four modules plus an optional fifth, as illustrated in the following table, specifying the ECTS associated with each module and their conversion into lecture hours (taking into account that 1 ECTS corresponds to 25 h of which about 7 h are classroom lessons) (Table 1).

Table 1. LTC modules

	Modules	ECTS	Hours
1	Theoretical background	0,5	3,5
2	Teacher's perspective with creation of own tasks	1	7
3	Student's perspective	0,5	3,5
4	Practical testing of a learning graph and peer reviewing of tasks	1	7
5	Essay (optional)	2	14
		3	21

The contents of each of the five modules are detailed below.

Module 1 aimed to introduce ASYMPTOTE and explore its potential implementations in Mathematics education. In this process: The continuum of educational settings was introduced, the role of the teacher in Technology Enhanced Learning concepts was defined, and ASYMPTOTE's uses in the various educational settings were described. Moreover, the participants familiarized with Online Pedagogy theoretical frameworks such as the Community of Inquiry and mobile learning pedagogy while they identified a pedagogical model specifically for ASYMPTOTE. Briefly outlined were also learning design principles and online teaching and feedback strategies. Finally, the sequencing of tasks in ASYMPTOTE was analysed, and the Learning graph was introduced.

In Module 2 the participants had the opportunity to explore and learn the functionalities and possibilities of ASYMPTOTE's web portal (account creation, portal navigation, etc.). Through the web portal the participants were able to search for, select existing tasks, and more importantly create their own in order to design a task sequence with multiple levels of difficulty, for a specific topic in Mathematics - or a learning graph as it is called in ASYMPTOTE. The various possible types of tasks will be explained (i.e. learning, training, reasoning, modelling; challenge, support) as well as the various answer formats (i.e. values, interval, multiple choice, etc.).

In Module 3 the participants familiarized with the system's mobile application and explored the students' perspective of ASYMPTOTE. The participants had the opportunity to solve task and use most of the app's functionalities. In particular, each participant was asked to carry out a learning graph prepared by the trainer, using the app. The trainers had to follow the progress of the learning graph by activating the Digital Classroom. At the end of the learning graph, the trainers had to explain in detail the functionalities of the Digital Classroom (how to create it, how to monitor, how to use the collected data).

Having clarified these aspects, the participants worked in groups of 3 or 4. They chose a mathematical topic (between grade 1 and grade 12)[1] and they had to generate a learning graph containing at least 6 tasks and possibly, among them, there should be at least 2 training, 2 reasoning, 2 modelling tasks. In addition, they had to create 4 more tasks of the challenging/supportive type. These were suggestions the trainers gave to the

[1] Depending on hat their degree program includes (if they are "School of Educa-tion" students they will have to create tasks for the primary school; if they are "Mathematics" students they will have to create tasks for the lower or higher sec-ondary school.

participants. We underline here that not all of the participants complied: some created more complex learning graphs.

In Module 4 the participants were introduced to microteaching. The tasks, learning graphs and lesson plans that the participants had designed through the course were applied and assessed by their peers. In particular, each group joined another group. Mutually, they tested their productions of learning graphs in order to show a simulation of implementation of the learning graph in a synchronous mode, through the Digital Classroom.

The Module 5 was optional and in it the participants had to develop an essay about the online teaching of mathematics using ASYMPTOTE in relation to other digital environments and the published relevant educational research results.

We will consider the results of LTCs conducted in Greece at the University of Aegean and in Italy at the University of Catania. Specifically, from each of these courses, we selected a LG created by a group of (future) teachers. The LGs chosen are LGs that are well structured and serve as good examples to illustrate to the reader the possibilities of the ASYMPTOTE system in order to answer the research question.

5 Findings

5.1 The LG from the University of Aegean

In the LTC that was delivered by the University of Aegean and the LTEE lab the participants were: 14 in-service mathematics teachers, 2 undergraduate mathematics students and 2 undergraduate primary students with a specific interest in mathematics. From the sum of the LGs produced by the participants we chose to analyse one that concerns systems of linear equations and aims at lower secondary students. The title of the LG is "Linear Systems" and its description: "Here we will learn how to solve systems of 2 linear equations with 2 unknowns!". Figure 2 shows the general structure of the particular LG.

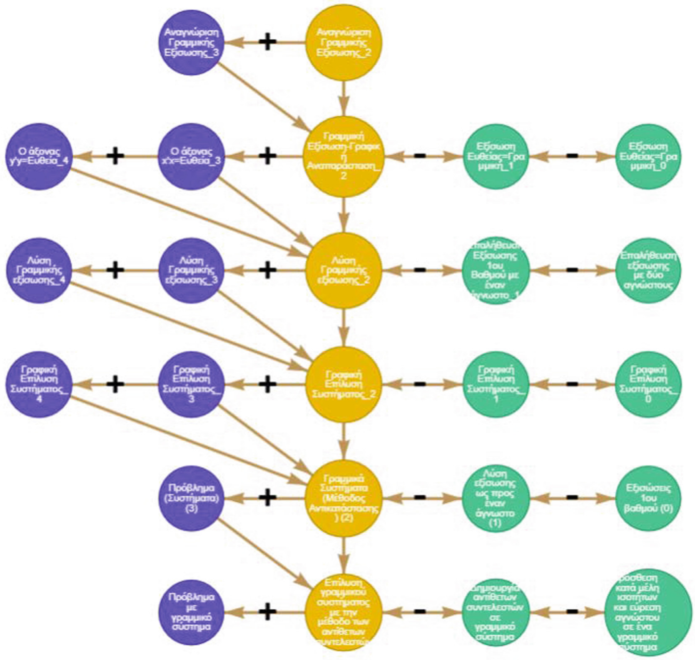

Fig. 2. The LG "Linear systems"

As we can see in Fig. 2 the LG consists of 6 main tasks, 9 challenge tasks and 10 support tasks. From the main tasks 4 are training and 2 are reasoning. Considering the challenge tasks, 2 of them are training, 4 of them are reasoning and 1 is modelling. From the total of the support tasks: 8 are training and 2 are reasoning.

Let's examine more closely the learning trajectory of this LG. The first main task is a multiple-choice question that falls into the training category. The students are asked to choose which of the following equations are linear:

a) $-3x + 5y = 0$
b) $2x - 3xy = 8$
c) $x^2 + 3y = -4$
d) $7x - 0y = 28$
e) $-x - \frac{2}{y} = 5$
f) $0x + 0y = -8$
g) $0x + 3y = 0$
h) $\frac{x}{3} + y = 13$

The task contains 2 hints and is connected to one challenge task that is also a multiple-choice question with the same desideratum *"Which of the following equations are linear"*:

1) $2(x + y^2) - 2(y - 3)(y + 3) + 3y = 9$

2) $(x + y)^2 - (x - y)^2 + 3y = 5$
3) $x(x - 2y) - (x - y)^2 + 3(x + y) + y^2 = 6$

This task is a reasoning task and contains 2 hints.

The next main task is a fill-in-the-blanks question that contains 2 hints and falls into the reasoning category. The task is defined as follows (the asterisks indicate the parts that appear as blanks to the students):

1) *The Eq. 4x − 2y = 6 represents a **straight line** that is parallel to the straight line **y = 2x** and crosses the y'y axis at the point (0,**−3**).*
2) *The Eq. 0x + 2y = 8 represents a **straight line** that is parallel to the axis **x'x** and crosses the axis y'y at the point (0,**4**).*
3) *The Eq. 3x + 0y = 6 represents a **straight line** that is parallel to the axis **y'y and crosses the axis x'x at the point (**2**,0).*

The task is connected to two challenge tasks and 2 support tasks. The first support task that is available to the user when they complete or fail to complete the main task, is a training task that uses the multiple-choice typology and contains 2 hints. The task is defined as follows: *"The equation $y = \frac{2}{3}x - 7$ that is parallel to the equation $y = \frac{2}{3}x$ and is intersecting the y'y axis at the point (0, −7) takes the form of a linear equation and is defined as:"*

- 2x − 3y = 7
- −2x + 3y = −7
- 2x − 3y = 21
- 2x + 3y = −21

If the user completes or fails to complete the first support task another one appears. This task is again a training task with 2 hints and a multiple-choice format. *"The equation y = −3 that is parallel to the x'x axis and intersects the y'y axis at the point (0, –3) takes the form of a linear equation and is written:"*

- x + y = −3
- 3x + y = 0
- 3x + 0y = −3
- 0x + y = −3

Now moving on to the challenge tasks. When a student successfully solves the second main task, the available challenge tasks are two reasoning multiple choice questions with 2 available hints each, that appear in a row. The tasks ask the students to find which of the following equations is linear and corresponds to the x'x axis (second main task's challenge task 1) and then to the y'y axis (second main task's challenge task 2):

- 0x + y = 0
- x + 0y = 0
- x + y = 0

- $0x + y = 1$

Moving on to the third main task of the LG under examination, it is again a multiple choice, reasoning task with 3 available hints. The tasks is defined as follows: "Which of the following pairs is a solution to the Eq. $4x + 3y = 18$? or differently: Which of the following points belong to the linear Eq. $4x + 3y = 18$?".

- (0, 6)
- (1, 5)
- (3, 2)
- (–3, 10)
- (–2, 8)

This main task in its sample solution also contains an image with the graphic representation of the correct answer to help the students visualize linear equation in question. This task relates to 2 support tasks. The first support task is multiple choice training task with 2 available hints. The question writes: *"Which of the following numbers verifies the equation* $-2x + 3 = 21$*"*.

- $x = -7$
- $x = 5$
- $x = -9$
- $x = -8$

The second support task is a multiple choice training task with 1 hint that is defined as follows: *"The pairs* $(x, y) = (-3, 5)$ *verifies the Eq.* $3x + 2y = 1$ *one of the following equalities applies"*.

- $3*5 + 2*(-3) = 1$
- $3*(-3) + 2*5 = 1$

The third main task refers to 2 challenge tasks. Both of these tasks are multiple choice task with 2 hints and a graphic representation of the answer in the sample solution section. The first one is defined as reasoning and the second one as training. The question to both tasks is defined in the same manner: *"Which of the following pairs are a solution of the equation* $y = -5$ *(third main task's challenge task 1)/*$x = 3$ *(third main task's challenge task 2)? or differently Which of the following points belong to the linear equation* $y = -5$ *(third main task's challenge task 1)/*$x = 3$ *(third main task's challenge task 2)?"* and have the following possible answers each:

- (5,0)
- (5,-5)
- (0,5)
- (3,5)
- (1,-5)
- (0,-5)
- (3,0)
- (-3,0)
- (3,3)
- (5,3)
- (3,5)

Here we can see that the creators have similar questions defined with a different type: training and reasoning. Which could be either a mistake or a sign that tasks depending on their place in the LG can be perceived differently.

At this point it is also important to note that as we already mentioned in the Sect. 2.1 a very important factor for task creation and one of the main elements that sets the limitations and the prospects for the creators when using technologies, is the answer types that the system can support. Here we can see that the creators of this particular LG seem to be trapped in only one answer format although ASYMPTOTE provides eight different answer types.

Moving on to the fourth main task of the chosen LG, it is a training task with vector (exact value) answer format, 2 available hints and a graphic representation of the answer in the sample solution section. The task is defined as: *"Solve the following linear systems:* $\begin{cases} x - y = 5 \\ 2x + y = 1 \end{cases}$" and asks for x and y values. This main task is connected to 2 support and 2 challenge tasks. Both support tasks are reasoning tasks with vector (exact value) answer formats, 1 available hint and a graphic representation of the answer in the sample solution section. The creators include the following pictures (Figs. 3 and 4):

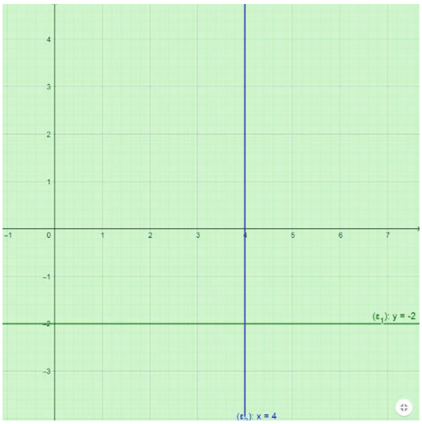

Fig. 3. Fourth main task's support task-1

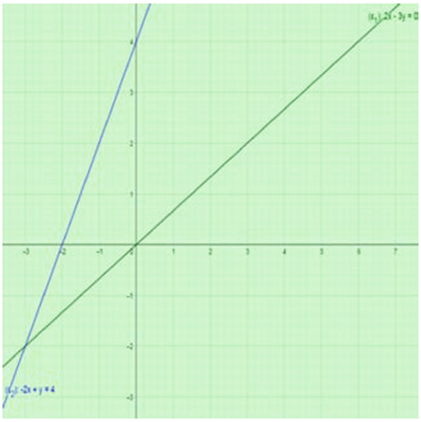

Fig. 4. Fourth main task's support task-2

and write: *"Refer to the picture and solve the system:* $\begin{cases} 2x - 3y = 0 \\ -2x + y = 4 \end{cases}$ (Fourth main task's support task 1) / $\begin{cases} -3y = 6 \\ 2x = 8 \end{cases}$ (Fourth main task's support task 2)*"* asking for x, y 's exact values. The challenge tasks are both training multiple choice tasks with 3 hints and a graphic representation of the answer in the sample solution section. Their definition is stated as follows: *"Graphically find the multitude of the linear system's solutions* $\begin{cases} 2x - y = 10 \\ 4x - 2y = 1 \end{cases}$ (Fourth main task's challenge task 1)/$\begin{cases} 3x + 6y = 9 \\ 2x + 4y = 6 \end{cases}$ (Fourth main task's challenge task 2)*"* and the available answers are these:

- One solution
- No solution
- Infinite solutions
- Two solutions

In order to have a more elaborated view of the components and the way that the LG in analysis was created, it is important to have a closer look at at least one set of its tasks. Figures 5. *5th mt's challenge*, Fig. 6. *5th main task*, and Fig. 7. *5th mt's support* show the user interface of the set of tasks that will be analyzed.

Fig. 5. 5th mt's challenge

Fig. 6. 5th main task

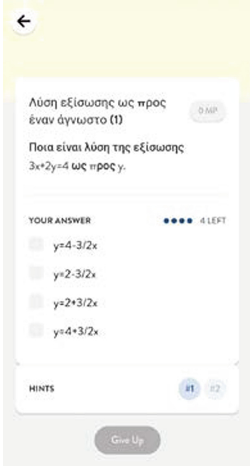

Fig. 7. 5th mt's support

The fifth main task is a training task with a vector (exact value) answer format. The task comes with a picture (Fig. 8) and writes: "Solve the system $\begin{cases} x + y = 20 \\ x + 3y = 44 \end{cases}$ by using the replacement method", asking for the values of x,y.

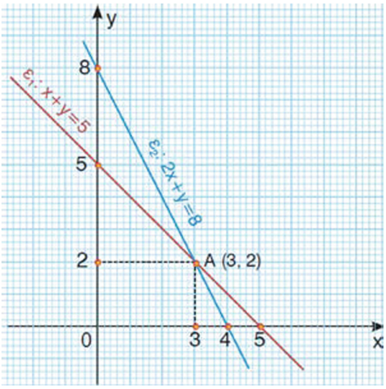

Fig. 8. Fifth main task

This task has 3 available hints. The first one urges students to Solve the first equation as to one of the two unknowns and make the replacement in the second equation as shown here: $\begin{cases} x + y = 20 \\ x + 3y = 44 \end{cases} \Leftrightarrow \begin{cases} x = 20 - y \\ x + 3y = 44 \end{cases} \Leftrightarrow \begin{cases} x = 20 - y \\ 20 - y + 3y = 44 \end{cases}$. The second hint gives the next step of the solution, asking the students to now solve the equation with a resulting unknown and find the value of that unknown as shown here: $20 - y + 3y = 44 \Leftrightarrow 20 + 2y = 44 \Leftrightarrow 2y = 44 - 20 \Leftrightarrow 2y = 24 \Leftrightarrow y = 242 \Leftrightarrow y = 12$. The third and final hint of this main task, is also the final step of the solution process and urges students to now go back to the first equation and replace the value of the unknown they found and finally calculate the price of the other unknown as shown below:

$$\begin{cases} x = 20 - y \\ y = 12 \end{cases} \Leftrightarrow \begin{cases} x = 20 - 12 \\ y = 12 \end{cases} \Leftrightarrow \begin{cases} x = 8 \\ y = 12 \end{cases}$$

The hints of this example are the steps of the task's solution and as we can see the creators not only give the student the steps as instruction, but they also made the choice to give to the students the mathematical methodology step by step. Other than the hints that are available to the students while attempting to find the solution, the task has also a sample solution that is available to the students when they fail to complete the task, or they answer correctly. The sample solution in this case contains the mathematical steps of the solution with no explanation:

$$\begin{cases} x + y = 20 \\ x + 3y = 44 \end{cases} \Leftrightarrow \begin{cases} x = 20 - y \\ x + 3y = 44 \end{cases} \Leftrightarrow \begin{cases} x = 20 - y \\ 20 - y + 3y = 44 \end{cases}.$$

$$\Leftrightarrow \begin{cases} x = 20 - y \\ 20 + 2y = 44 \end{cases} \Leftrightarrow \begin{cases} x = 20 - y \\ 2y = 44 - 20 \end{cases} \Leftrightarrow \begin{cases} x = 20 - y \\ 2y = 24 \end{cases}.$$

$$\Leftrightarrow \begin{cases} x = 20 - y \\ y = \frac{24}{2} \end{cases} \Leftrightarrow \begin{cases} x = 20 - y \\ y = 12 \end{cases} \Leftrightarrow \begin{cases} x = 20 - 12 \\ y = 12 \end{cases}$$

$$\Leftrightarrow \begin{cases} x = 8 \\ y = 12 \end{cases}$$

And is combined with the following graphic representation of the answer (Fig. 9):

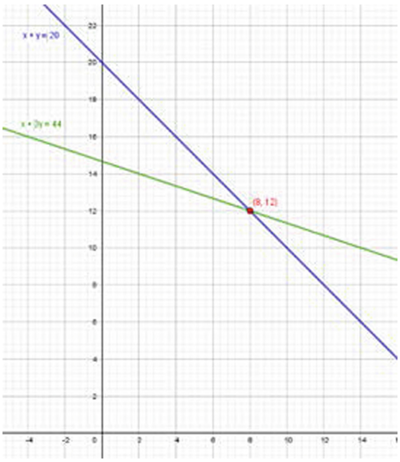

Fig. 9. Fifth main task's sample solution

By the analyses of the hints and sample solution, we can speculate that the creators of this LG have not fully understood the way the system works and when the hints are available to the student. It is true that when a student views a hint loses points from the said task, but the hints are available throughout the solution process. The hints that were created for this task, provide the student with the answer step by step not only in theory but also in mathematical terms. This means that all the students, no matter if they know how to solve this task, would be able to complete it, with the only difference that they gain fewer points. As far as the sample solution we can note that it lacks in theory. If a student no matter the hints could not solve this problem, they would need more than the mathematical solution to fully understand the way that these types of tasks can be solved. Including a graphic representation is a very good practice but in this case, it should be accompanied by a text explanation, describing the steps and why one makes them.

To continue, this main task is combined with 2 support tasks and 1 challenge task. The first support task is a training multiple-choice task with 2 available hints. The definition of the task is the following: *"What is a solution of the Eq. $3x + 2y = 4$ with respect to y"* and the available answers are:

$y = 4 - \frac{3}{2}x$
$y = 2 - \frac{3}{2}x$
$y = 2 + \frac{3}{2}x$
$y = 4 + \frac{3}{2}x$

The first available hint writes: *"Try to leave at the one side of the equation the unknown y, as shown below: $3x + 2y = 4 \Leftrightarrow 2y = 4 - 3x$"*. The second hint, is the final step of the solution prosses and advises the students: *"If the coefficient of the unknown is different than 1, then you can divide by the coefficient of the unknown, as shown below:"*

$$y = \frac{4 - 3x}{2} \Leftrightarrow \mathrm{y} = \frac{4}{2} - \frac{3x}{2} \Leftrightarrow \mathrm{y} = 2 - \frac{3x}{2}$$

Finally, the sample solution of this support task, is the mathematical answer of the task which is actually the combination of the previous 2 hints.

The challenge task that is connected to the fifth main task is a modelling task with a vector (exact value) answer format. The problem of this task is stated as follows: *"A farm has hens and rabbits. The heads of all animals are 26 and the legs of all animals are 72. Find how many hens and how many rabbits the farm has"*. The answer to this task requires the exact number of hens and the exact number of rabbits. Let's take a look at its hints and sample solution. This task has 2 available hints. The first one is defined as follows, describing the thought process of mathematizing the data: *"First we need to use the data to create two equations with two unknowns, that is, a system. We assume that x are the hens and y are the rabbits. Then we know that the heads of all animals are 26 which translates into: $x + y = 26$ and since the legs of all animals are 72 (2x feet of hens + 4y feet of rabbits) we can also write: $2x + 4y = 72$"*. The second hint, in this case, does not offer the solution of the task, as we saw previously. It provides the students with the methodology saying: *"Now we solve the system of two equations that we created, using the method of replacement"*. Finally, the sample solution of this task combines the previous hints, but also provides the mathematic solution of the problem step by step:

"Let's say that x represents the number of hens and y the number of rabbits. Then: x + y = 26 (For the heads) and 2x + 4y = 72 (For the feet). So now we only have to solve a system with two unknowns:

$$\begin{cases} x + y = 26 \\ 2x + 4y = 72 \end{cases} \Leftrightarrow \begin{cases} x = 26 - y \\ 2(26 - y) + 4y = 72 \end{cases}$$

$$\Leftrightarrow \begin{cases} x = 26 - y \\ 52 - 2y + 4y = 72 \end{cases} \Leftrightarrow \begin{cases} x = 26 - y \\ 2y = 72 - 52 \end{cases}$$

$$\Leftrightarrow \begin{cases} x = 26 - y \\ 2y = 20 \end{cases} \Leftrightarrow \begin{cases} x = 26 - y \\ y = \frac{20}{2} \end{cases} \Leftrightarrow \begin{cases} x = 26 - y \\ y = 10 \end{cases}$$

$$\Leftrightarrow \begin{cases} x = 26 - 10 \\ y = 10 \end{cases} \Leftrightarrow \begin{cases} x = 16 \\ y = 10 \end{cases}$$

In this task it is clear that the use of the hint and sample solution functions are better utilized.

To finish the presentation of this LG we move on to briefly describe the sixth and final main task, which is a training multiple-choice task with 3 available hints. The task asks the students to solve the linear system: $\begin{cases} 2x - 3y = 16 \\ 3x + 4y = -10 \end{cases}$ and pick the correct answer:

- (x, y) = (2, 4)
- (x, y) = (2, −4)
- (x, y) = (−2, 4)

This main task is connected to 2 support tasks and one challenge task. The support tasks are training multiple-choice tasks, with 2 available hints. The first task is defined as: *"In the following linear system make opposite coefficients for x or y:* $\begin{cases} 2x - 3y = 16 \\ 3x + 4y = -10 \end{cases}$. *By what numbers would you multiply the equations?"* and the possible answers are:

- 2 and −3
- 3 and −2
- 2 και 3

And the second task refers to the same system asking the students to *"add by members and find the unknown y",* giving the possible answers:

- y = 4
- y = −4
- y = −3

Finally, the challenge task is a training multiple choice task with 2 available hints. The problem that is defined at this task is the following: *"In one parking lot there are 50 vehicles, cars and motorcycles. If all vehicles have 170 wheels, find how many cars and how many motorcycles there are."* the available answers are:

- 35 cars and 15 motorcycles
- 15 cars and 35 motorcycles
- 30 cars and 20 motorcycles

This LG in general has a good flow on its learning trajectory with increasing difficulty and clear tasks. The support tasks do help students understand the topic better by allowing repetitions, offering a simplified version of the related main task, or by splitting the mathematical process in smaller parts. The challenge tasks, on the other hand, show a bigger level of difficulty, in comparison with the main task that they are connected to, giving students the much-needed challenge. It is important to note that all tasks are justified as main, support or challenge from their place in the LG and in connection with their accompanying tasks. A task that is challenge in one LG can be main or support task in another.

Moreover, from this description we noticed that the use of hints and sample solution was not consistent throughout the LG. This might have been due to a lack of understanding of their functions, or pure design skills.

Another very important finding was the difficulty of the creators to incorporate more than 3 answer type formats in their task design. This could be due to lack of competence with the system and its answer formats or sign that the creators tend to get trapped in the answer formats that they are more familiar with and do not go easily outside their comfort zone.

Finally, a confusion was noticed regarding the creators' ability to characterize their tasks as training, reasoning, and modelling. This could be due to a mistake or due to the different possible perceptions of the same type of task depending on their place in the LG.

5.2 The LG from the University of Catania

The LTC carried out at the University of Catania was offered to 12 students in a master's degree course in mathematics, who worked in groups of 3 students each. Among the LGs produced, we examine a LG aimed at lower secondary school students concerning the topic of powers. The title of the LG is *"Powers"*, and its description is: *"In this graph we deal with various questions relating to powers through games and reasoning. Have fun!"*. Figure 10 shows the general structure of the LG.

As we can see in Fig. 10, the LG consists of 6 main tasks, 4 challenge tasks and 2 support tasks. Let us begin by examining the learning trajectory envisaged by the future teachers. The first main task "*To begin with*" falls into the learning category, in fact it occurs in the fill-in-the-blanks typology and invites students to review the definition of power. It is stated as follows (the asterisks indicate the parts that appear as blanks to the students and which they are to fill in using the words between the asterisks): *"Raising to **power** is the operation that associates two numbers, called respectively **base/exponent** and **base/exponent**, with a third number called power, which is obtained by **multiplying** between them as many **numbers equal** to the base as the **exponent** indicates*".

The next main task "*Product of powers*" is a training task in which it is asked to solve the following equation: $8^4 \bullet 8^x = 8^4$. Associated with this task is the support

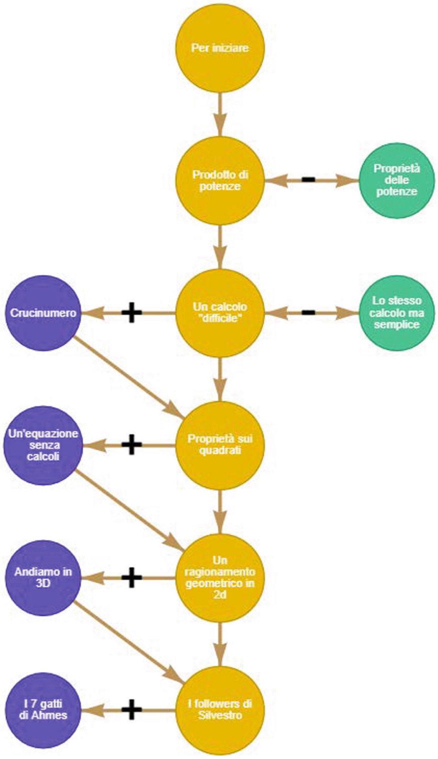

Fig. 10. The LG "Powers"

task "*Properties of powers*". It takes the form of a learning task that invites students to indicate which of its five options is correct. It therefore takes the form of a repetition of a topic, the properties of powers, which, once known, can be addressed in the main task to which it is linked.

We focus more closely on the next main task, "*A difficult calculation*", to which the future teachers have attached both a support and a challenge task. The main task is a training task and asks to solve the following task: "*What is half of* $\left(\frac{1}{2}\right)^{50}$*?*". Figure 11 b) shows how the task appears in the ASYMPTOTE app. It is a multiple-choice task and among the 4 options only one is correct. In the hints, the future teachers do not go too far, considering that they have also associated a support task. They write as Hint 1: "*Remember the properties of powers*". These properties may not have been seen by all the students during the LG because the task that proposes them is the previous support task, which is only compulsory for those who fail the main task to which this support task is linked at least twice, i.e., "*Product of powers*". So, if the student who gets this far does not find the suggestion enlightening and cannot solve the task, he/she can benefit from a specific support task: "*The same calculation but simple*" (Fig. 11 c)), which as the title already suggests is a simplified version of the main task. This is referred to as the training task and the response format is exact value. In its Hint 1, it recalls the property of the quotient of powers: "*The quotient of two or more powers that have the same base is a power whose base is the same and whose exponent is the difference of the exponents*". The solution states that "*Simply apply the power property 'quotient of two powers having the same base"*.

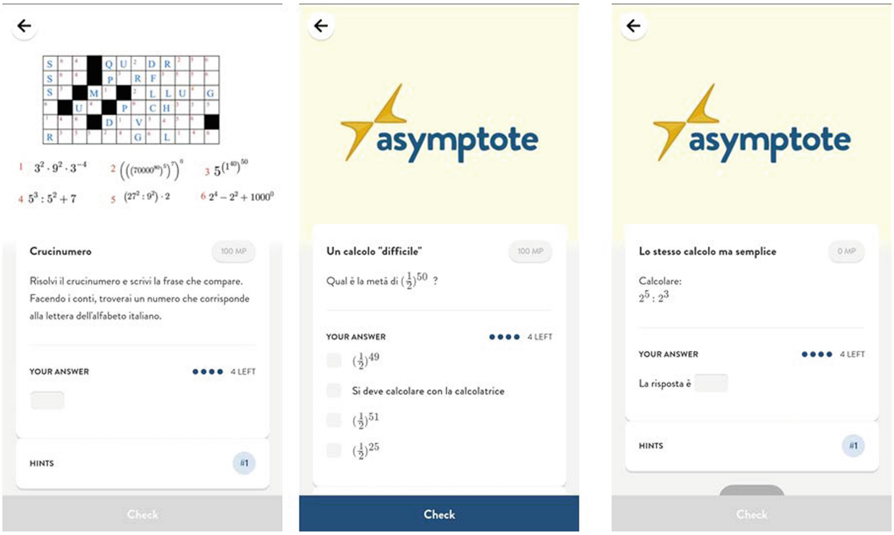

Fig. 11. a) challenge task, b) main task, c) supportive task

For those students who have correctly solved the main task, there is the possibility of a challenge task "*Crucinumero*" (Fig. 11 a)). This is a Reasoning task that involves solving six expressions containing powers in which sums, differences, products, divisions and powers of powers are involved. It is therefore necessary to have a good grasp of the properties of powers in order to solve these expressions. The result of each of these expressions is a number and a letter of the alphabet in bi-univocal correspondence must be associated with it. Hint 1, in fact, reads: "$A = 1; B = 2; C = 3; \ldots$". This association then makes it possible to place this letter within the crucinumero given in the task image and finally obtain a complete sentence in Italian. The sentence, which we translate below into English, is what is to be reported as the solution to the task: "*I am square I am perfect if I stretch a little, I becomes a rectangle*".

The next main task is "*Properties on squares*" and is a reasoning task. The delivery is: "*What can we say about the statement* $x^2 < 0$?". It is prefigured as a multiple-choice task, with 4 options of which only one is correct, namely "*It is false whatever value x takes*".

Associated with this task is a challenge task: "*An equation without calculations*", also a reasoning task which involves, as the title suggests, reasoning instead of calculations. The delivery is: "*For which values of x is it true that* $(x + 4)^{(x+2)} = 1$". Here the type of answer is Set, in fact it is not necessary to state the two solutions of this equation in a specific order.

This is followed by the main task "*A 2D geometric argument*", whose delivery is as follows: "*How much is the sum* $1733^2 + 2 \times 267 \times 1733 + 267^2$ *worth? Write down the exact value, calculating any powers*". It is a modelling task and has the following image associated with it (Fig. 12).

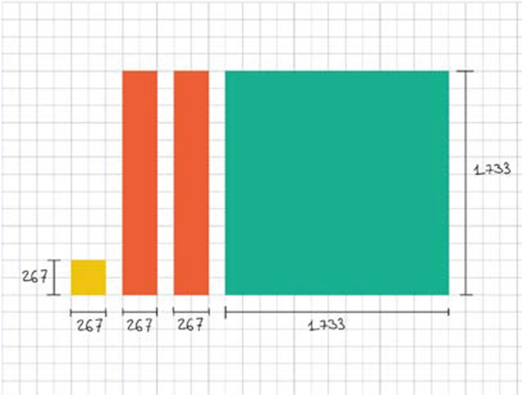

Fig. 12. "2D geometric argument"'s image

Students are then asked to convert the expression into geometric terms (1733^2 can be read as the area of the square of side 1733;…). And the associated response type is exact value. Associated with this task is the challenge task "*Let's go 3D*", which involves modelling similar to the previous task. The task reads: "*Calculate the sum of the first ten cubes:* $1^3 + 2^3 + 3^3 + 4^3 + 5^3 + 6^3 + 7^3 + 8^3 + 9^3 + 10^3$*. Write down the exact value, calculating any powers*". And here too, the task is associated with an image (Fig. 13).

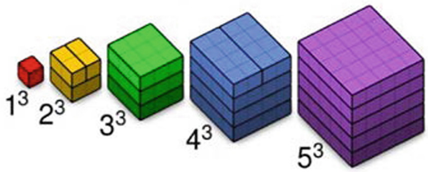

Fig. 13. "Let's go 3D"'s image.

The LG concludes with the main task "*Silvestro's followers*" which is a reasoning task with the following delivery: "*One day Marilena, Federica and Silvestro meet in the park to chat. Silvestro tells them that for 64 days he managed to have:*

1 follower on Instagram on the first day,
2 followers on the second day,
2^2 *on the third day,*
2^3 *on the fourth day,*

and so on until day 64…

Federica and Marilena are not very convinced that Silvestro is that famous, but they decide to calculate how many followers he got on day 64″. The type of answer is multiple-choice: the options do not indicate the final result, but how to set the calculation in order to eventually solve the problem.

Associated with this task is a challenge task "*The 7 cats of Ahmes*", also a reasoning task that goes like this: "*In a property there are 7 houses, in each house there are 7 cats, each deed catches 7 mice, each mouse eats 7 ears of corn, each ear gives 7 heqats of corn. How many things are there in all in this property?*". The type of answer is multiple-choice and even here in the options, similarly to the related main task, the exact final number is not given, but the setting of the calculation to be done to obtain it.

Looking at the LG in its entirety and with respect to task types, we can observe that this LG consists of 12 distinct tasks as follows: 2 learning, 3 training, 5 reasoning and 2 modelling. In general, the learning trajectory proceeds from the definition of power elevation and then exploits this concept and the properties of powers with increasing levels of difficulty. The supportive tasks are actually designed to be supportive by allowing the repetition of the property of powers or by offering a simplified version of the related main task, so as to allow a possible learner in difficulty to appropriate or retrieve the knowledge that is useful for him to move forward in the LG. The challenge tasks, on the other hand, are in analogy with the relative main tasks and are really designed for any students who may find the main task simple or immediately solvable and may be willing and/or pleased to come across something more challenging for them. However, we observe that hints included in tasks are almost always equal in number to 1. This leads us to assume that the future teachers may not have fully understood the functions of the hints or the reasons for this may also be related to their design skills.

It also emerges that out of 9 response formats made available by the ASYMPTOTE system, the future teachers worked with only 4 of them, namely: 3 exact value, 5 multiple-choice, 3 fill in the blanks and 1 set. This leads us to the following observations: on the one hand, the future teachers seem to have a lack of competence with the system and its response formats; on the other hand, it also seems that they tend to get trapped in the response formats with which they are most familiar and do not easily get out of their comfort zone.

6 Discussion and Conclusion

LTCs allowed participants from various countries to get in touch with the ASYMPTOTE system and to receive training on it. In this paper, we focused on LTCs conducted in Greece and Italy.

From the analysis of the data, with the aim of answering the research question, we can state that the way the ASYMPTOTE system is used by the LTCs participants is quite close to what was envisaged by the system's designers. In fact, we observed how ASYMPTOTE, from the teacher's point of view, provides guided templates to create tasks adapted to the needs of each student and the process of creating learning graphs is user-friendly. This enabled the LTCs participants to design customised learning experiences for their students quickly and efficiently. The LTCs participants had freedom of choice in the mathematical topic to be covered and then could literally indulge in the types of tasks to be created, not only by taking into account the instructions given by the LTC on task types (training, reasoning, and modelling), but also by making use of some of the different response formats provided by the ASYMPTOTE system. Despite the fact that the LTCs participants did not use all 9 possible answer formats and, in a sense, were limited to an almost repetitive use of answer formats, it is undeniable that the tasks they produced are varied and offer a plethora of possibilities that the ASYMPTOTE system allows. The choice and flanking of challenge or support tasks to the main tasks constituting the learning trajectory devised by the LTCs participants was also accurate. This shows how they correctly encapsulated the adaptive functionality of ASYMPTOTE, making predictions about the possible learning processes of the potential students to whom the LG is addressed.

From the proposed LGs, it can be seen that the LTCs participants have designed challenge tasks, with the knowledge that they are provided to students who have successfully solved the main task. Thus, ASYMPTOTE makes learning challenging, but at the same time, the challenging tasks are optional, so that learning does not become intimidating for the user. The choice of support tasks has also been calibrated. In such tasks the LTCs participants sometimes simplified the main task and other times provided the users with the missing knowledge and thus increased the learner's effectiveness towards achieving the set learning outcomes.

In guiding the potential users to whom these LGs are addressed, the participating LTCs made a few inaccuracies: sometimes the hints are not in sufficient number to support the development of reasoning, or they guide the student too much in the conclusion of the task, setting the solving strategy for him/her to employ. At other times, it is the sample solution that is not written appropriately to enable the user to understand the reasoning followed by the designer. We believe that practice in task design, implementation, and use of LGs with users, and thus gaining a little more experience, may be the keys to overcoming even these inaccuracies.

We can conclude that our findings show that the ASYMPTOTE system is an effective platform for the creation of adaptive tasks and LGs.

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Augmented and Virtual Reality in Computer Science Education

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Abstract. This paper shares and analyzes some experiences in the use of augmented and virtual reality, presenting technologies and methodologies leveraged for implementing three different projects. Such projects, carried out at the high school level, are used for discussing on the relevance of augmented and virtual reality for providing fundamental concepts on computer science education. To this end, an assessment toolkit is provided for an effective evaluation of this kind of activities.

Keywords: Virtual Reality · Augmented Reality · Computer Science Education

1 Introduction

In the field of learning innovation, there is a wide discussion on the use of Augmented Reality (AR) and Virtual Reality (VR) for creating immersive learning environments in educational settings. VR creates a virtual world aiming to substitute the real physical world, instead AR enhances real world perceptions with virtual elements.

Some authors [1,2] emphasize the advantages of using such technologies in education, for instance by explaining the opportunity of representing abstract concepts in a "tangible" way. Other researchers are less enthusiastic [3], emphasizing that, rather than focusing on the physical verisimilitude of a virtual scenario, it is more important to focus on the *cognitive realism* of an immersive learning scenario because learning environments and tasks create conditions for immersion, not technologies themselves. Moreover, nowadays teachers are not digital natives and the educational world often suffers from an inertial resistance to changes. Such resistance is usually preconceived and stubbornly conservative, perhaps linked to the effort of staying continuously updated with evolving technologies and therefore having to constantly rethink the teaching practice.

The authors believe that AR and VR must surely claim their space in school education: such technologies can foster an interdisciplinary approach and can be very motivating, from the point of view of both students and teachers. Moreover, VR and AR can be of paramount importance in teaching computer science. In fact, such topics can convey various aspects of the discipline: designing virtual

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reality scenarios involves not only computer graphics but also the design of the user interaction, for example by programming the system response to the events generated by users. Furthermore, the system has to be inserted into a network (the 3D viewer, the controller, the personal computer) that can be extended for integrating sensors that are in the local space or even in the Internet of Things (IoT).

This paper reports some educational experiences related to the process of creating, developing and testing AR and VR applications at the high school level. Such projects have been carried out in a three-year time frame during extracurricular activities in an Italian High School for technological technicians, called *"Girolamo Caruso"* and located at Alcamo, Sicily. This kind of technical school contains a three-years specialization period in the Information and Communication Technology (ICT) field [4]. For this reason, such context is particularly suited for testing the effectiveness of using AR and VR for computer science education and ICT in general, since many related and fundamental topics are already part of students' curriculum, e.g. programming languages, computer networks, microcontrollers.

The paper presentation has two main objectives: (a) sharing our experiences, reflecting on the possibility of integrating them into curricular teaching and proposing enabling assessment toolkits to this end; (b) analyzing the motivational impact that AR and VR technologies can have on students basing on their own perceptions. In Sect. 2, the related work on the use of AR and VR in education is briefly analyzed. Section 3 presents AR and VR projects carried out with students. In Sect. 4, the learning methodologies for developing such projects are presented and discussed. Section 5 analyzes students' opinions and propose an assessment toolkit useful for bringing this kind of activities in the curricular framework. Section 6 concludes the paper.

2 Related Work

In education, new technologies are continuously introduced to improve the process of learning and AR/VR technologies, both hardware and software, are often used for providing an immersive experience. The adoption of such technologies in education has long been discussed. Some authors [1,2] emphasize their advantages and explain many of their opportunities, such as:

- representing abstract concepts in a "tangible" way;
- creating realistic scenarios in the classroom, to overcome the limitation of pure theory;
- completing textbooks with virtual objects that can add information in specific parts of the text;
- the opportunity of doing in virtual contexts, manipulating objects without risks of personal injuries.

Other researchers are less enthusiastic [3], emphasizing that, rather than focusing on the physical verisimilitude of a virtual scenario, it is more important to focus on the *cognitive realism* of an immersive learning scenario because learning environments and tasks create conditions for immersion, not technologies themselves.

This point is somehow controversial, since some works point out that technology matters. For instance, Hussein and Nätterdal present a qualitative study [5] that examines the benefits of VR educational applications in comparison to same applications on mobile. By analysing results, they found that VR is especially effective in subjects where an interactive environment is needed. VR offers an immersive experience, involvement and promotes active learning in comparison to mobile applications.

A recent survey [6] recaps potential VR issues that could hinder its widespread utilization in mainstream education, including lack of training, high costs, insufficient realism, hardware/software usability, and perceived ineffectiveness. Also, misconceptions about VR and health concerns (e.g., cybersickness, eye strain, safety hazards, etc.) were two major barriers to its adoption in classrooms. However, with the technology becoming more powerful and affordable, many of the aforementioned issues and limitations are now solvable, making the future routine classroom usage of VR increasingly feasible and desirable.

The same survey points out that, despite the various learning benefits and positive findings regarding VR-based instruction, K-12 and higher education classrooms have, thus far, failed to witness VR implementation at a significant scale. The majority of VR interventions in the literature have been limited to professional development such such as medicine [7], nursing [8], chemistry [9], rather than curricular learning in education. Moreover, to the best of our knowledge, the use of AR and VR in teaching informatics is not common, except for few cases [2]. Our paper focus on the development of AR and VR projects for conveying computer science pillars, by providing a proper assessment methodology to teachers.

An interesting aspect on the use of AR and VR in the classroom is pointed out in the work by Ślósarz et al. [10]. Their work aims to investigate the connection between VR and emotions that can motivate students to be more active in the didactic process. They monitored participants' moods by using questionnaires and the results show that VR significantly modifies learners' emotions, contributing to the reinforcement of positive emotional states, and in the case of those with low self-esteem, it also decreases negative emotional states. As a conclusion, they find that VR can be used as a didactic tool to facilitate the teaching-learning process at various levels, by making the didactic process more attractive, there by influencing learners' emotions positively.

Our research corroborates results from Ślósarz et al. , showing that AR and VR technologies can positively influence students in their attitude towards the didactic process, enabling intrinsic motivation as a key aspect of learning.

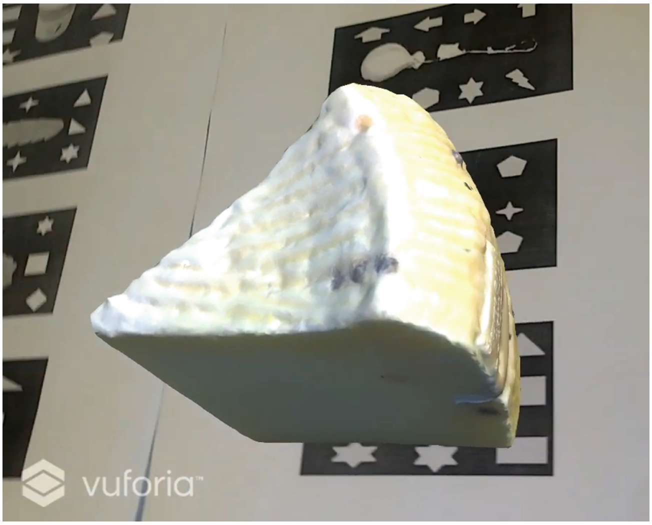

Fig. 1. Marker-based augmented reality

3 Experiences

This section presents the most significant projects made by students and supervised by the authors. Such projects have been mainly realized by using the Unity (www.unity3d.com) platform and the Oculus Rift viewer.

Regarding 3D development platforms, Unity has been leveraged for creating scenarios, positioning lights and placing objects. Unity allows the developer to program the interaction with objects by using an objected-oriented language such as `C#`. Unity is a platform very demanding in terms of memory and computational power, however it is quite easy to use. It was very suitable for our students, that knew the reference programming language for being curricular in their learning path.

The Oculus Rift viewer has been used because it is supported by the Unity platform and it is capable of an immersive kind of experience.

3.1 Market Exhibition

In the context of a market exhibition hold by local agro-food producers, we created an AR project that permits to see 3D reproductions of food by framing the product marker. An example is reported in Fig. 1, relative to a typical food product of the Sicilian territory.

The application also permits to access an interactive menu containing information on the product itself (e.g., historical notes, characteristics, ingredients). In this case, the app was developed using Unity in combination with the *Vuforia* libraries (https://developer.vuforia.com/). Students also created 3D models by using standard techniques such as 3D scanning and photogrammetry.

Fig. 2. Immersive virtual reality

3.2 Academic Museum of Technology

This project aimed at creating an interactive and immersive exhibition that can completely involve visitors, providing information in real time without the need for additional staff and leaving visitors free to deepen their knowledge on displayed objects by interacting with them. A physical and virtual location was created by showing vintage typewriters, electronic typewriters, first-generation cell phones and so on.

In Fig. 2 it can be seen a visitor wandering around the virtual museum by using a 3D viewer and interacting with an object by taking it from the ground (the video can be viewed on https://www.youtube.com/watch?v=LDm9_QuW4Bc). As part of this project, virtual contents were produced and the entire environment was created, by designing and programming the user interaction.

3.3 Arduino Day

Using previous experiences as a starting point, a virtual scenario was created, allowing users to play a treasure hunt whose purpose was to recover doubloons and release them inside a chest. The starting place of the virtual scenario, as seen inside the Unity platform, is depicted in Fig. 3. The reuse of pre-existing virtual objects allowed students to concentrate on programming the game, rather than on creating the scenario.

The game was enhanced with the possibility of interacting with an Arduino [11] board, in order to obtain a so-called "sensory virtual reality", being a virtual reality that can be modified when living the experience, by means of stimuli coming from real-world sensors. As a *proof-of-concept*, the VR project

Fig. 3. Virtual Scenario

leveraged a brightness sensor that was used for reflecting the luminous changes of the real environment inside the virtual one, modifying the brightness of the virtual scenario in real-time during the experience. A brief video is available at the following link https://www.youtube.com/watch?v=7ALZ9ConVK4. By opinions collected during our demo, we found that the "sensory virtual reality" is very promising as an effective way for overcoming some issues related to VR, such as the isolation from the real world.

4 Learning Methodologies

This section discusses the most significant learning methodologies used in the realization of the projects presented in Sect. 3.

4.1 Project-Based Learning

The *project-based learning* is a learner-centered learning methodology. It was born with the intention of favoring, compared to more traditional teaching methods, the development of communication skills, problem solving skills, critical thinking and self-directed learning.

This method shares several similarities with another methodology, the problem-based learning, because both starts the learning process from an "authentic" problem. Students do not need to know all possible solutions nor the ways to get to the solution. Students, therefore, have the responsibility of defining the problem, describing the useful knowledge already in their possession, identifying the new knowledge to be learned for solving that particular problem and establishing the steps to be taken. This process takes place under the guidance of a facilitator who supports the learners in the research and problem solving phase. It is evident that this point of view differs from traditional teaching, in

```
VoidOnTriggerEnter(Collider other){ }
    // a phenomenon is activated when an object enters
    // in the designated area
VoidOnTriggerExit(Collider other){ }
    // the exact opposite of enter
VoidOnTriggerStay(Collider other){ }
    // the phenomenon persists as long as you stay
    // in the designated area
InputGetKeyDown(KeyCode.letter event){ }
    // just press a key of your choice to run the event
InputGetKeyUp(KeyCode.letter event){ }
    // the event is executed as soon as the key is released
```

Fig. 4. Documentation on scheduled events in Unity

which learning is not a discovery but generally constitutes of a simple application of pre-established solutions, already proposed by the teacher and easily reconstructed using didactic materials, such as notes or textbooks. Project-based learning, however, is characterized by the focus on design activities and aims at the production of "things", for example an artifact or a software program.

For this reason, project-based learning was particularly suitable for our purposes and was mainly used to make students acquire skills and competencies on the Unity platform. By monitoring the self-learning of a group of 5 students over a period of two weeks, it was noted that they prefer video tutorials as a starting point for their training and only subsequently they consult written documentation. In addition, during their training they managed to locate the most useful API (Application Program Interfaces) and felt the need to produce written documentations that could serve as a reference, such as the extract reported in the listing of Fig. 4.

It has been noted that project-based learning can bring several benefits:

- better transmission and duration of knowledge;
- improving skills for seeking information, dealing with problems and group communication;
- greater motivation and interest;
- students learn to collaborate and work in a group;
- students develop their own critical spirit, facing complex problems;
- students improve technical writing skills by producing documentation.

The main disadvantages of this methodology are connected to the fact that didactic roles are substantially reversed:

- teachers cannot teach and this can be frustrating from their point of view;
- students lose the opportunity to be inspired by their teachers.

Furthermore, project-based learning is only effective if learners continuously receive feedback on their work. This paradigm, which is part of a formative evaluation, is a further upheaval for teachers and learners, commonly used to reasoning in terms of summative evaluations.

4.2 Peer Education

The *peer education* is a methodology that favors horizontal transmissions of knowledge and considers equality a possible push for a better learning, since students become active subjects of their training and not mere content-receivers.

Since one of the problems to overcome for the implementation of this methodology is the need for the peer educator to have adequate basic training, this methodology was used as soon as some students had gained sufficient knowledge of skills and competencies, acquired by using other methodologies, such as the project-based learning described in Section 4.1. At this point, skilled students began to transmit knowledge, emotions and experiences to other peers. Through the comparison between different points of view, the exchange of ideas, the analysis of problems and the quest for possible solutions, a dynamic between peers was activated, which did not exclude the possibility of using collaboration and support of experts on the subject.

The students under observation, as teenagers, were among the most natural recipients of peer education: in this phase of life in which the changes to be managed are many and profound, it is also thanks to the group of peers that each adolescent affirms his identity, outlines spaces of autonomy from the family and builds external affective relationships. In this case, peer education made it possible to obtain the following advantages:

- it favored the development of metacognitive skills;
- students assumed responsibilities when teaching to peers;
- the language between peers did not need linguistic intermediation.

One of the main disadvantages of peer education is the difficulty of evaluating its impact for summative evaluations. In this case the problem did not arise (as the projects were extracurricular ones) but this point can make it hard to implement such a methodology in the curricular framework. To overcome this limitation, a possible solution is explored and proposed in Sect. 5.

5 Analysis and Assessment

In order to analyze the perception that students have about their school education and in particular regarding the possibility of using AR and VR as a vehicle for increasing awareness of their knowledge, a questionnaire was proposed to involved students. Table 1 shows the answers given in Likert scale (1 = not at all, 5 = very much) by students who have already used technologies related to AR and VR (33 out of 64). It can be seen an enthusiastic approach for VR technologies and a very strong will to deepen their curricular use. Note, however,

Table 1. Opinions of students who have already used VR technologies

Questions	Answers
Do you believe that working with VR technologies can be useful in improving your programming skills?	3.87
Do you think knowing how to use VR technologies can be useful for finding work in the future?	4.06
Would you like VR technologies to be introduced in your training curriculum?	4.3

Table 2. Opinions of students who have never used VR technologies

Questions	Answers
Do you believe that working with VR technologies can be useful in improving your programming skills?	4.19
Do you think knowing how to use VR technologies can be useful for finding work in the future?	4.03
Would you like VR technologies to be introduced in your training curriculum?	4.19

how there is some perplexity about the effective improvement of programming skills by students, probably due to the fact that this topic was already stressed on their curricular activities, though different technologies and methodologies were used.

Table 2 shows the answers given in Likert scale (1 = not at all, 5 = very much) by students who have never used technologies related to AR and VR (31 out of 64). Opinions provided by students are very clear regarding their desire to introduce/deepen VR technologies during their educational path. However, the methodologies tested in the presented projects cannot be directly implemented in curricular teaching, mainly because they do not easily fit into a summative assessment process.

A further step is necessary in this direction. In fact, the methodologies discussed in Sect. 4, that have been chosen and tested in this work, are typically combined with formative assessment. In order to implement our work in curricular teaching, we need to reconcile such methodologies with summative assessment, since this kind of assessment is required in the Italian high school system. Some initial efforts have been made by the authors in order to provide both formative and summative assessment in a smooth way [12]. In this case, we propose a similar approach, by developing a specific toolkit well-suited for AR and VR projects.

In particular, we start thinking about the formative evaluation, which can be translated into summative evaluation at the end of the learning process. For the formative assessment of our learning project implementation, we identify the

Table 3. Competencies

Abbreviation	Competencies
C1	Use computational thinking and algorithms to tackle problems by developing appropriate solutions
C2	Configure, install and manage processing systems and networks
C3	Knowing how to read technical reports and document for group activities

fundamental competencies to be assessed, as shown in Table 3. Then, we develop a specific project rubric, as shown in Table 4, which highlights competencies and levels achieved.

The goal of the project rubric is the evaluation of competent actions in terms of knowledge application and solution strategies. The project rubric can then be accompanied by other rubrics, such as behavioral rubrics [13], which describe knowing act during the development of reality tasks and metacognitive rubrics [14], describing the ability to reconstruct and illustrate the path carried out in terms of methods, contents, strategies and personal involvement.

In order to use our learning project also in the curricular planning, it is necessary to have a summative evaluation with marks in tenths, as a requirement of the Italian school system. We propose an approach that can be considered a little bit unorthodox, since it admits the possibility of translating the formative evaluation into marks in tenths. This approach is corroborated by two observations:

– competencies include knowledge and skills and thus by evaluating the former ones we also evaluate the latter ones;
– in our case the project outcome can be a prototype and/or a technical documentation for exposing contents and techniques – such objects present aspects suitable for summative assessments.

We point out that the contrary translation from marks to competencies should never be done, since the evaluation of knowledge and skills, especially if conducted by traditional tests, satisfies only a partial aspect of competencies. The different levels are then translated into marks only at the end of the learning process and not during the process, because this would lead to common disadvantages, such as focus on marks and not on the learning process, students' frustration.

At the end, to obtain marks from the observation of levels, we propose the translation reported in Table 5. The translation can be done for each competency under observation and the final mark is given by the average of the assessments. Please note that, in the Italian education system, a positive mark is from 6 to 10. For this reason we recommend to take into consideration at least both project

Table 4. Project rubric

	Poor	Initial	Basic	Intermediate	Advanced
C1	The student is unable to correctly identify problems and developing solutions, even if he is guided by teachers or peers	The student is able to identify problems and developing solutions by leveraging the help giving by teachers or peers	The student is able to identify problems and developing solutions in an almost completely autonomous way	The student is able to satisfactorily identify problems and developing solution, in a completely autonomous way	The student is able to satisfactorily and effectively identify problems and developing solution, in a completely autonomous way
C2	The student is unable to configure, install and manage processing systems and networks, even if he is guided by teachers or peers	The student is able to configure, install and manage processing systems and networks by leveraging the help giving by teachers or peers	The student is able to configure, install and manage processing systems and networks in an almost completely autonomous way	The student is able to satisfactorily configure, install and manage processing systems and networks, in a completely autonomous way	The student is able to satisfactorily and effectively configure, install and manage processing systems and networks, in a completely autonomous way
C3	The student is unable to understand essential information, even if he is guided by teachers or peers	The student is able to understand essential information by leveraging the help giving by teachers or peers	The student is able to understand and report essential information, in an almost completely autonomous way	The student is able to understand and report information with a certain degree of details, in a completely autonomous way	The student is able to understand and report information with a wealth of details, in a completely autonomous and personal way

Table 5. Marks for competencies

Level	Mark in tenths
Poor	3
Initial	5
Basic	6
Intermediate	8
Advanced	10

rubrics and behavioral rubrics for summative assessments. In this way, students with an initial level of competencies can be likely reach a positive score if their learning path is characterized by a positive attitude.

6 Conclusion

This paper shares some of the most significant school experiences that have been carried out for producing AR and VR applications. These experiences have been mostly conducted as extracurricular activities. However, AR and VR technologies excite students, by having a strong motivational impact on their training path. We therefore believe that it is possible and necessary for computer science teachers (and not only) to include AR and VR into the frame of curricular learning, in order to direct students towards the future of computing and society.

For this reason, this paper presents some AR and VR projects, by discussing some aspects of our implementation, such as technology and contents. The paper also describes learning methodologies used in this work and proposes an assessment toolkit well-tailored for evaluating this kind of activities in computer science education.

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The Rational Numbers in a Pre-service Mathematics Teacher Educational Path Highlighting the Role of Feedback in the Formative Assessment

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Abstract. In this study we present an experimental research which analyses the role of feedback in a Formative Assessment path in solving an arithmetic task for university students, future mathematics' teachers. The educational path has been divided into various phases, in which pre-service mathematics teachers worked in small groups. Teachers had to solve an arithmetic task concerning rational numbers. The workshop has been held online and, indeed, the role of technology is very important, since it ensures some important interactions. In this paper, is shown in which way giving and receiving feedback could make the students aware of the mathematical concepts. This activity has favored an improvement in communication and in problem solving strategies. In particular, feedback has a very important role in this Formative Assessment process, since it gives multiple perspectives for students and teachers, it makes the communication and argumentative skills improve and it makes the students aware of their own work revealed while analyzing and evaluating the others' work.

Keywords: Formative Assessment · Pre-service mathematics teachers · Rational numbers · Technology · Feedback

1 Introduction

In this paper, we present an experimental research, realized through a workshop, in-spired by a good practice carried out within the UMI DIGIMATH group (https://sites.google.com/unisa.it/digimath/home-page?authuser=0) on research topics concerning Formative Assessment (FA) and feedback (Carotenuto et al., 2022).

FA, as a teaching practice, is one of the most important fields of Mathematics Education research (Mathematics Assessment Program: http://map.mathshell.org).

There is much research that refers to the implementation of this practice in primary and secondary school related to argumentative skills (Sabena et al. 2020, Fazio et al. 2020). Moreover, in the Italian National Guidelines, the attention is stressed over the argumentative skills that are "relevant to the formation of an active and conscious citizenship, in which each person is available to listen carefully and critically to the other and to a comparison based on the reference to relevant topics" (MIUR 2018, p. 12).

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Less studied is the university environment where opportunities for interaction between peers are not frequently widespread. We believe that the use of this practice with university students, future teachers, may play a key role to favor the learning and meaning construction.

We started from the assumption that one of the difficulties that the student, future mathematics' teacher, manifests in solving a problem is taking for granted and obvious the reasons behind the choices of problem-solving strategies. Therefore, an online workshop concerning a FA activity has been designed and implemented in the Primary Education Sciences Degree Course and in the Mathematics Degree Course, specifically in Mathematics Education subjects for Mathematics pre-service teachers (PTs), of which the authors are lecturers of the courses.

The workshop activities follow a structure divided into various phases in which the students worked in small groups: solving a problem concerning rational numbers, peer assessment of the course participants' solutions and sending an improvement feedback, subsequent modification of the solution proposal to the problem after the feedback received from peers and finally a feedback from the course teachers on the solutions' evolution. The effectiveness of peer assessment workshops is based on some theoretical reference that we will specify in the following.

The role of technology is fundamental, as the workshop is online. It plays an important role in peer assessment, ensuring the random distribution of the tasks to be reviewed and the monitoring and sharing of feedback from teachers.

Finally, the digital nature of the learning environment requires a reflection on the role it assumes in shaping FA of the argumentation processes.

The aim of this paper is to analyze how the communicative aspect related to solving processes of a mathematics problem by students, improves through the assessment of problem's solution produced by peers.

2 Theoretical Framework

2.1 Formative Assessment and Feedback

The FA processes allow students to verify their learning levels and plan and implement the necessary strategies to achieve the pre-established learning objectives (Cusi et al., 2017). This occurs through interactions with the teacher and classmates.

According with Black and William (2009), FA become a teaching practice, in which "evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited".

These activities also support the professional teachers' training allowing collaboration between them (Albano et al., 2020).

As Wiliam & Thompson (2007) stated, FA is realized through five key strategies involving three different agents (teacher, learner, and peer), and three different processes (where the learner is going, where the learner is right now, how to get there), as following:

1. clarifying and sharing learning intentions and criteria for success;
2. engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding;
3. providing feedback that moves learners forward;
4. activating students as instructional resources for one another;
5. activating students as the owners of their own learning.

The relationships among all the elements are shown in Table 1.

Table 1. Aspects of Formative assesment

	Where the learner is going	**Where the learner is right now**	**How to get there**
Teacher	**1** Clarifying learning intentions and criteria for success	**2** Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding	**3** Providing feedback that moves learners forward
Peer	Understanding and sharing learning intentions and criteria for success	**4** Activating students as instructional resources for one other	
Learner	Understanding learning intentions and criteria for success	**5** Activating students as the owners of their own learning	

In the FA practices, a crucial role is played by the feedback given and received by peers. The feedback referred to, concerns the information that each student provides on the activity produced by other students and receives on his own activity. According to Ramaprasad (1983), the feedback becomes formative only if it allows the student to evolve his/her own performance.

Therefore, it is necessary that the feedback highlights errors, inaccuracies and possible deficiencies. Hattie and Timperley (2007) identified four types of feedback:

1. feedback about the task, concerning the comprehension of the task and how it is being accomplished or performed;
2. feedback about the processing of the task, concerning the processes underlying tasks or relating and extending them;
3. feedback about self-regulation, concerning the awareness in monitoring, directing and regulating their own actions toward the learning goal;
4. feedback about the Self as a person, concerning personal emotional aspects and individual assessment.

For the feedback and peer review in a FA workshop, the teacher has to design different phases of work aimed to involve students. Students become aware and responsible of their own learning. For this, the teacher chooses and defines the assessment criteria to let the students be capable of giving feedback. According to FaSMed (Aldon et al., 2017; Cusi et al., 2017) the feedback must follow these specific criteria: correctness, completeness and clarity. These criteria are applied by the questions linked to them:

- Correctness: "Are there any mistakes in the result or in the resolution process? Are all the answers given? Is the theoretical reference, if any, correct? Are the mathematical symbols used correctly?"
- Completeness: "Are there parts or leaps of reasoning missing? Or unwarranted conclusions? Can you find all the necessary steps in the reasoning?"
- Clarity: "Is the reasoning expressed clearly and unambiguously? Are the sentences understandable?"

2.2 Digital Resources: The FA Workshop Online

Technology plays a major role, as it allows to support the FA processes in its three main functions: sending and viewing; processing and analysis of the data collected during the lessons; provide an interactive environment, where students can interact to work individually or in groups on a task or to explore mathematical/scientific content (Albano et al., 2020a).

The use of the digital platform in organizing a workshop allows to customize both the types of tasks and the feedback by the PTs (Serpe & Frassia, 2018). The use of adequate resources facilitates peer-education which is a fundamental element of a person-centered environment.

The person-centered perspective argues that the success of a learning path and the positioning of the individual in his or her cultural context is favored in environments where the individual's well-being is valued through inclusion, respect, trust, freedom of choice, self-efficacy (Rogers and Freiberg, 1994). According to Rogers and Freiberg (1994), the sense of belonging to the social group made up of students and the teacher in a "family dimension" becomes an engine of learning towards relevant quality standards and a support to overcome difficulties and challenges intrinsic to the encounter with knowledge.

Therefore, the workshops require the construction of a person-centered environment that guarantees the success of the path. Indeed, it is asked participants to tackle challenging mathematical issues, such as argumentation, and to expose themselves to peer evaluation. One of the most significant consequences of a person-centered approach is that teachers and pupils co-transform themselves, thus overcoming the barriers between those who teach and those who learn.

The FA workshop online is structured in the following phases (Sabena et al., 2020):

- *Setting up the laboratories*: the teacher distributes the tasks to the students, assigns a time for the resolution of the tasks, defines the evaluation criteria.

- *Problem solving (Task 1)*: all students receive the same mathematical problem to solve and the criteria with which their solution will be evaluated; then, each student uploads his / her resolution to the platform.
- *Peer evaluation*: each student receives the anonymous solutions of other classmates, randomly chosen; then examines them and provides each of them one or more feedback, according to the shared evaluation criteria; each student receives the feedback produced in the previous step by the peers who have examined their solution.
- *Re-elaboration of the solution of the problem*: each student re-elaborates his own solution based on the feedback received and offered.
- *Feedback*: the teacher trainer makes available on the platform the resolutions that he considers interesting for the class, chosen among those produced by the students themselves and conducts a collective discussion.

The educational objectives of an online peer assessment workshop identified as part of teacher training are as follows (Carotenuto et al., 2022, Albano et al., 2020b):

- The workshop aims to develop the mathematical thinking of those who participate in it by using the valuable contribution of the feedback. It is referred both to that the trainees can receive from peers and both on that of their own work of reviewing peer products. Indeed, it allows them to reflect on representations and resolutions of the problem, different from their own.
- PTs are also asked to undertake a formative evaluation intervention, which can be understood as a simulation of a practice that they will be called upon to implement in their professional life. In this task they are guided by evaluation criteria provided by the trainer, with possible application examples: this activity, especially if repeated in the case of peer evaluation workshop cycles, allows future teachers to develop skills in the practice of formative evaluation.
- Finally, the peer evaluation proposal, being accompanied by the introduction of the criteria, can also be used by the trainer to share with PTs which are the evaluation criteria that will be adopted during the examination, or at least part of them, communicating implicitly also what for the trainer has more value in mathematics and in its teaching.

Referring to this theoretical framework, the research questions we try to answer are:

1. How does providing and receiving feedback on problem solving help improve PTs' communication and their problem-solving strategies?
2. How does feedback make the PTs more aware of their knowledge?

3 Research Methodology: The Workshop Online

The online workshop involved 180 primary PTs of Primary Education Sciences degree course, and 40 secondary PTs of Mathematics Degree Course from the University of Bari.

The teachers of these courses are the authors of this paper. The experiment lasted about three weeks and was performed using distance learning. The participants were divided into groups of four PTs from the same course, generating 40 groups in the Primary Education Course and 10 groups in the Mathematics Course. During the online workshop, the Microsoft Teams platform facilitated the interactions among students and with teachers. The designed workshop was developed in the following four phases with the relative requests to the students:

Phase I: Resolution of the arithmetic task concerning rational numbers. After identifying a group leader, each group was asked to process the answers of the task by producing a text shared into the group.

The task proposed a diagram of a vegetable garden planted with potatoes, cabbages and carrots (See Fig. 1). While the fractions of potatoes and cabbages are known, the PTs were asked to find what fraction of the garden was planted with carrots. They had to provide a geometric, algebraic and arithmetic representation of the solution.

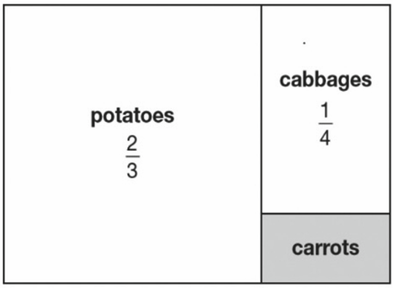


Fig. 1. Vegetable garden

Phase II: Review of the solutions provided by peers, answering the questions relating to the criteria of correctness, completeness and clarity as declared above in the theoretical framework;

Phase III: Request to eventually modify their solutions on the basis of the feedback made and received;

Phase IV: Feedback from the lecturers of the course on the evolution of solutions.

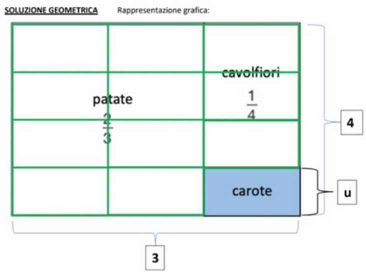
All the phases were carried out through the Microsoft Teams platform that allowed: the interactions among students in the working group; the immediate sending of feedback; the processing and analysis of both the data collected during the online workshop and the protocols delivered by the students after the three phases.

4 Discussion and Results

In this section some interesting PTs' products are discussed, after solving the task and after receiving or giving feedback about the solutions' review of another group by answering the questions about correctness, completeness, and clarity. In the following tables (Tables 2, 3 and 4), in the first column there is the phase of the workshop referred to. In the second column there are some PTs' products authors select and the translation made by the author. In the square brackets the questions related to feedback's criteria.

In the third column there are some of the authors' analysis referring to the theoretical framework.

Table 2. Example 1

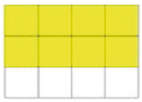
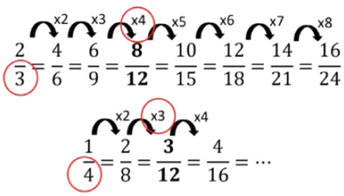
Phase of the workshop	PTs' products	Authors' analysis
Phase I: First solution by group 3	"The unit is contained 3 times on the base and 4 times on the height of the rectangle (vegetable garden). By repeating the sample unit of measurement on the whole figure, we obtain 12 rectangles (we operate as in the "base by height" formula, i.e., we make 3 x 4 = 12)." 	The students divided the vegetable garden into 12 rectangles, identifying the shape of the carrots as a unit measure.
Phase II: review of the solutions and Feedback by group 2	[*questions concerning Clarity: "Is the reasoning expressed clearly and unambiguously? Are the sentences understandable?*] We don't understand why you divided the vegetable garden exactly into 12 rectangles. It isn't clear why you have 12 rectangles and not more or less.	They received feedback in which the peers highlighted that they didn't explain precisely why they divided the vegetable garden into 12 rectangles. The given feedback stimulates group 3 to provide an argumentation for the chosen strategies.

(*continued*)

Table 2. (*continued*)

Solution revised by group 3 after the feedback by group 2	"Looking at the figure, we note that the surface of the vegetable garden planted with carrots (colored part) represents ¼ of the part cultivated with cabbage and carrots, because folding the paper along the sides of rectangle of carrot, the colored part (carrots), we discovered that it is the unit measure. It fits 4 times in the column of cabbages and carrots and 3 times in the base of the vegetable garden.	The solution revised proposed by group 3 is enriched with more elements of clarity. Indeed, the solvers explain how they obtained the answers to the problem by making the choice of the solution. strategies evident and arguing them.

Table 3. Example 2

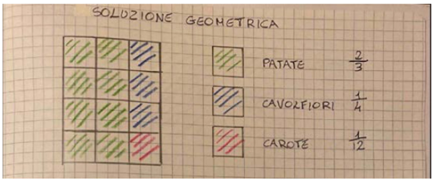
Phase of the workshop	**PTs' products**	**Authors' analysis**
Phase I: First solution by group 11	**Geometric solution** We want to reproduce the integer, showing in it the single fractions of potatoes and cabbages. For doing that, we choose an **equivalent fraction** to ⅔ and to ¼, which has the denominator in common, that is 12.  The equivalent fraction to ⅔ of potatoes is 8/12, so dividing the integer into 12 parts, we colored 8 of them  In the same way, the equivalent fraction to ¼ is 3/12, for this reason, by dividing the integer into 12 parts, we consider only 3 of them.	This is the Graphic representation in which students say that they need to use the equivalent fractions to divide the vegetable garden with the same unit measure.
Phase II: Feedback by group 13	*[questions concerning Completeness: "Are there parts or leaps of reasoning missing? Or unwarranted conclusions? Can you find all the necessary steps in the reasoning?"]* "Yes, in the geometric approach it should be explained what equivalent fraction means"	In this feedback there is a request for completeness highlighted by the lack of the meaning of equivalent fraction
Solution revised by group 11 after the feedback by group 13		In the solution revised, the group 11 added this figural explanation of equivalent fractions to the previous solution highlighting the mathematical properties necessary to construct them. This request of completeness made the PTs more aware of the mathematical concepts involved.

In the three previous examples, it is shown how feedback improves the solution from both communicative and argumentative point of view. Furthermore, students struggle to use mathematical justification, which becomes more and more rigorous and correct.

Finally, we report some examples about two groups among 50 of them, that synthesize some interesting elements answering our research questions. Indeed, in the following transcriptions, is highlighted how this process allowed them to listen to the other, to rethink to their own solution while giving feedback to another solution, to become aware of their own work taking another point of view:

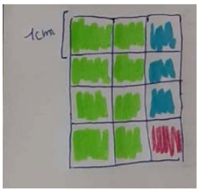
- ***Group 14***: "…as it also happened to us students, they begin to become aware not directly of their own work, but by reading another and making their own the ideas of others, they are able to understand if their work is of quality or not. In this case, the potential of feedback is great: by reviewing, or listening to others, we are willing to listen to the other and take another point of view, this only enriches ours. We had to understand, establish the concreteness of the proposal made by the other based on our experience… And with this we enriched ourselves and understood the limits of our work".

Table 4. Example 3

Phase of the workshop	PTs' products	Authors' analysis
Phase I: First solution by group 20	 Considering that the whole vegetable garden corresponds to 1 and that the two known parts are 2/3 and 1/4 of the unit, we have identified the lowest common denominator between 3 and 4, that is 12, and we have divided the vegetable garden into 12 equal parts. We calculated 2/3 of 12, that is 8, and colored 8 parts of 12 (potatoes). We calculated 1/4 of 12, that is 3, and colored 3 parts of 12 (cabbages). What remained was a square, that is 1/12, corresponding to the fraction cultivated with carrots.	The geometric solution provided by Group 20 is an arithmetic one, together with a geometric representation.

(*continued*)

Table 4. (*continued*)

Phase II: Feedback from the group 15	*[questions concerning Correctness: "Are there any mistakes in the result or in the resolution process? Are all the answers given? Is the theoretical reference, if any, correct? Are the mathematical symbols used correctly?"]* "The procedure lacks correctness and proof, as the properties of plane geometry have not been recalled …some of the geometric questions are missing. In the geometric solution, no theoretical reference was made to plane geometry, and in this case to the rectangle." *[questions concerning Completeness: "Are there parts or leaps of reasoning missing? Or unwarranted conclusions? Can you find all the necessary steps in the reasoning?"]* "…as in the geometric part the rectangle has been divided into 12 equal parts, but without a preliminary demonstration, therefore the division as drawn and described remains unjustified". *[questions concerning Clarity: "Is the reasoning expressed clearly and unambiguously? Are the sentences understandable?"]* "...As for the geometric part, the reasoning is not clear, in fact there is the error between the LCM and the lowest common denominator, moreover the figure no longer corresponds to that given in the task"	The feedback declares the lack of correctness since the theoretical reference to the Geometry is missing The feedback highlights the lack of geometric proofs necessary to justify the proposed solution. The answer is incomplete. Also on clarity, the feedback highlights the confusion in the use of incorrect words
Solution revised and/or answers after the feedback	**Geometric solution modified**  If we give to each side of the square the value of 1cm we obtain a base of 3cm and a height of 4cm. Therefore, the area will be 12 cm^2 A=bxh → 3x4=12 cm^2 Potatoes= ⅔ x 12 cm^2 = 8 cm^2 Cabbages= ¼ x 12 cm^2 = 3 cm^2 Carrots= 1/12 x 12 cm^2 = 1 cm^2	After receiving the feedback, Group 20 changed the solution. The changes made to the solution make the difficulties of the students emerge. Indeed, Geometry is confused with measurement (1 square becomes 1 cm^2) or formula for area. It is also evident that difficulties in finding a geometric solution independent of arithmetic or algebraic one emerges.

- ***Group 6***: "In the rereading we will revise and have another point of view, which will enrich ours. A qualitative evaluation aimed more for us than for the other group, thinking beyond the moment that we read a solution and review another's work".

5 Conclusion

The review carried out by the students was revealed to be an adequate tool for the workshop. The feedback's analysis sent by each group of peer students and the analysis of the changes made after receiving the feedback highlighted that this type of activity has favored an improvement in communication and in problem solving strategies. It is interesting to observe how the revision had a double value: on the one hand receiving the feedback improved the solution of the problem, on the other hand the revision phase itself allowed them to have a greater awareness of the mathematical concepts involved. This also improves their own proposal both from a communicative point of view and for the mathematical contents. This work has allowed PTs to gain greater awareness of their mathematical knowledge and the importance of communication for their future role as prospective teachers.

Finally, feedback has a very important role in this FA process, in the sense that it gives multiple perspectives for students and teachers, it makes the communication and argumentative skills improve and it makes the students aware of their own work revealed while analyzing and evaluating the others' work.

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Evaluation of Pedagogical Strategies Based on Socio-Affective Scenarios in a Virtual Learning Environment

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Abstract. This article aims to evaluate Pedagogical Strategies based on Socio-affective Scenarios in a Virtual Learning Environment (VLE). The Pedagogical Strategies (PS) are actions planned and used by the professor in their educational practice, in order to assist in the construction of knowledge. For this, it is necessary to analyze the characteristics of the participants in order to personalize the teaching. Thus, the Scenarios are representations of a combined social and affective profile that relate to each other. Therefore, 83 PS created for the Socio-affective Scenarios were applied in two graduate subjects in the distance modality. The methodology adopted was qualitative. The data collection instrument was an evaluation questionnaire on the application of PS made available online. The target audience of the research were 6 professor and 3 monitors who responded and pointed out changes in the application of PS. The results indicate the need to create a tool that makes the automatic recommendation of the Socio-affective Scenarios and indicates the corresponding PS for the professor and monitor. In addition, the importance that the PS had to intensify interactions and exchanges in the VLE was highlighted, as well as the personalized follow-up that students received by professors and monitors.

Keywords: Pedagogical Strategies based on Socio-affective Scenarios · Virtual Learning Environment · Social and Affective Profile

1 Introduction

Over the last ten years, Distance Education (DE) has been transforming and, consequently, increasing the offer of virtual courses in order to take education to all corners of Brazil [1]. The DE demands greater autonomy from the student, since he must access the Virtual Learning Environment (VLE), manage his study time and make contact with the professor in case of difficulties [2]. Thus, in this type of teaching, it is more difficult for the professor to identify the social and affective aspects of their students. From this perspective, it is essential that professor apply Pedagogical Strategies (PS) capable of streamlining their classes, so that the student feels welcomed. PSs are influenced and

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modified through the needs identified in a given context [3]. In this sense, this study starts from a reflection on the Socio-affective aspects evidenced in Virtual Learning Environments (VLE).

Therefore, the aims of this article is to evaluate Pedagogical Strategies based on Socio-affective Scenarios in a Virtual Learning Environment (VLE). In this investigation, the Scenarios are understood as the intersection between the indicators of the Social Map and Affective Map, both are part of the VLE of the Cooperative Learning Network (ROODA, acronym in Portuguese). The Social Map presents the social relationships established in the environment, and the Affective Map comprises the subjects' moods.

Thus, the work is organized into six sections. Next, the Socio-affective Scenarios are explained. In Sect. 3, the Pedagogical Strategies are conceptualized. In Sect. 4 describes the research methodology. In Sect. 5 the results are presented. Finally, in the last section the conclusions are listed.

2 Socio-Affective Scenarios

The Cooperative Learning Network (http://ead.ufrgs.br/rooda) was conceived by Patricia Alejandra Behar in the year 2000 according to constructivist principles, within the interactionist epistemological conception of Jean Piaget [4] in order to encourage the cooperation process. ROODA is free, subject-centered software that provides students with access to materials, interaction tools, synchronous and asynchronous communication, as well as exchanges and submission of activities. This VLE has already been used by more than 70,000 users [3, 5].

In this study, the VLE used is ROODA, as it is one of the official platforms of the Federal University of Rio Grande do Sul (Brazil). It is possible to collect data from subjects and extension courses, as well as analyze the performance of students through Social and Affective Maps.

The Social Map (SM) is generated by the data provided using the tools Chat, Contacts, Forum, Groups and the comments in the Library and Web Portfolio. SM enables the formation of sociograms through the amount of user interactions. In it, it is possible for the professor, in a visual way, to follow the Socio-affective relationships established in ROODA. Thus, SM currently has six indicators [3], based on student profiles: Absence (the person logs into the VLE and does not reply the group's requests), Collaboration (the user contributes by sharing files, content, images, pages and links), Feelings of separation from the class (the student sends messages and publishes in the VLE, but does not receive response from peers), Drop out (the student never accessed the teaching activity in question, not establishing exchanges), Informal groups (the student exchanges messages with three or more classmates and through these exchanges we can observe the existence of groups among the participants) and Popularity (the subject keeps higher frequency interactions compared to other group members, based on an average among all participants), shown in Fig. 1.

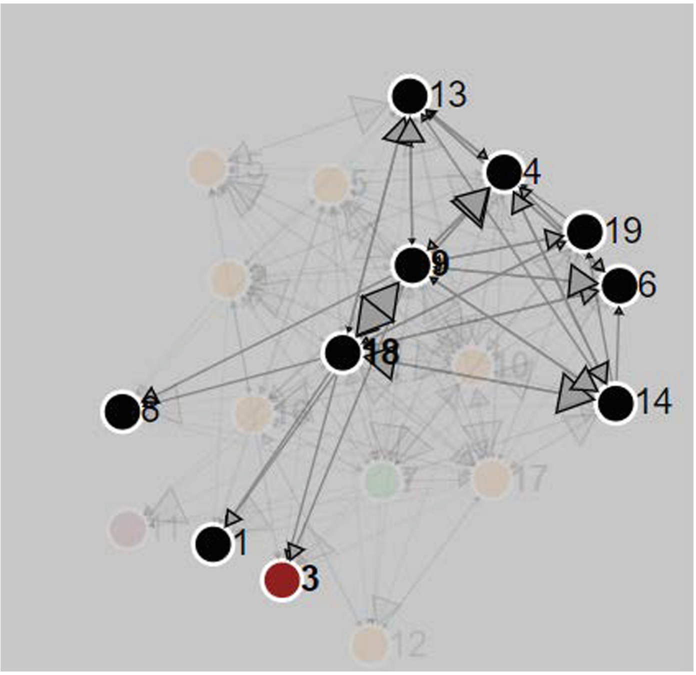


Fig. 1. Social Map. Source: http://ead.ufrgs.br/rooda.

On the other hand, the Affective Map (AM) was developed by Longhi [6] with the purpose of helping the professor to detect the affective moods of the students. The AM considers as communication resources the tools Chat, Forum and Logbook. It qualitatively analyzes the interactions that took place in ROODA. The AM is composed of four moods, clockwise, from right to left: Satisfied (indicates that the student expresses joy, enthusiasm, satisfaction and pride for accomplishing the task), Animated (evidences that, within the affective family, the student demonstrates hope, interest, serenity and surprise to face the learning challenges), Discouraged (suggests that the learner demonstrates or represses guilt, fear, shame and sadness for not being able to follow the content) and Dissatisfied (students express or try not to show irritation, contempt, aversion, and envy), illustrated in Fig. 2.

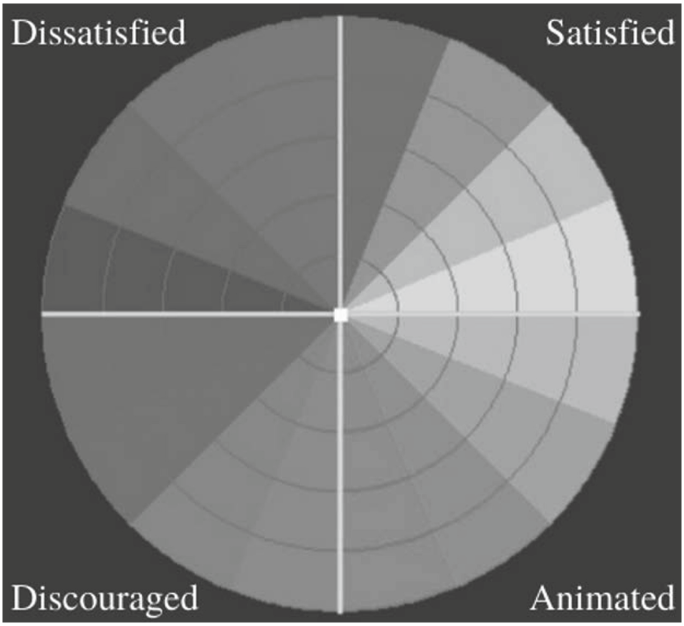


Fig. 2. Affective Map. Source: http://ead.ufrgs.br/rooda.

In the study by Akazaki, Machado and Behar [7] a total of 38 Socio-affective Scenarios were mapped in 13 case studies, based on the six social indicators of the SM and the four moods of the AM (https://drive.google.com/file/d/1Hq-Ci6ZCRPnlN5t390UqFebWeKK1Au-9/view?usp=sharing).

Therefore, the various tools that make up the ROODA are fundamental as pedagogical spaces, as it is through them that the professor can streamline their classes, support the student and mediate the educational process in order to promote learning. The VLE's communication tools also allow the establishment of relationships between Distance Education subjects, which arise in response to the strategy adopted by the professor. However, for this to occur, a methodological change is needed, which means knowing the student's profile and proposing Pedagogical Strategies (PS) that can place them at the center of the teaching and learning process [8]. Thus, the importance of PS is described in the next section.

3 Pedagogical Strategies

Pedagogical Strategies (PS) do not have a basic theory defined in the literature, there are several explanations that are generally very comprehensive or are related to certain teaching paradigms. The PS contemplate numerous visions, as they can refer to methods, techniques and practices that act as resources with the purpose of achieving pedagogical objectives. PS are defined as the way each professor puts his personal model into practice. That is, the professor can structure different strategies that aim to achieve results that can promote and mediate the learning of their students [3, 9].

For Ribeiro [8], when the professor defines or re-elaborates PS, according to the students' context, he manages to minimize the difficulties that occur in VLEs. The resulting impact can be positive or negative, being marked by the approximation, or distance, between the individual (student) and object (content or other individuals). Therefore, when they generate negative feelings, such as the feelings of separation from the class, discouragement or dissatisfaction, they influence the student's actions, which can trigger learning stagnation or a more drastic decision, drop out. From this perspective, the development of PS should have as its main focus the understanding of the student participating in a subject or course and the objective to be achieved.

The creation of PS requires constant reflection and awareness of the intended purpose of its use. According to Amaral [9], every time the professor develops ways to achieve a purpose and establishes actions in the educational process, he is weaving PS. The author emphasizes the importance of considering the student's previous development and its context, especially the social and affective aspects.

Thus, it is understood that only by observing these behaviors the professor can act in a personalized way and devise more pertinent strategies, contemplating the individual needs of each student. In this context, the author Barvinski [10] established criteria to be followed for a PS to be considered adequate in terms of structure, language and direction of actions, as can be seen in Fig. 3.

Fig. 3. Criteria for the elaboration of a Pedagogical Strategy. Source: created by authors (2022) based on Barvinski [10].

The criteria adopted for the design of PS are:

Direct Language: use direct language, having the professor and the monitor as subjects.

Self-assessment: suggest that the professor carry out a self-assessment of his/her pedagogical procedure, verifying the points of his/her practice that contribute to the student's Socio-affective situation (if positive) or to restructure the activities and contents, seeking to reverse the student's negative valence.

Resources: indicate the tools that can be used to perform the action, namely: Chat, Library, Contacts, Logbook, Forum and Web Portfolio.

Action: point out the action to be taken by the professor or monitor.

In this context, taking into account the 4 criteria adopted for the conception of PS the Barvinski's [10], the 38 Socio-affective Scenarios were considered and a PS was elaborated for each of the 6 VLE tools used to generate the Social Maps and Affective Map, totaling 228 PS (https://drive.google.com/file/d/1Bl5jbDO4E-SjDXIWUXkOSUtl0UYQLO2p/view?usp=sharing).

An example of a Pedagogical Strategy developed for the "Animated" and "Collaboration" and "Feelings of separation from the class" Socio-affective Scenario using the Chat tool is: "*The student showed to be animated, to be collaborative, although, feelings of separation from the class. In this way, he is probably motivated to interact and share materials with his colleagues, but even then, they are not reciprocating in the interactions. The Chat tool can be an interesting choice so that this subject can share, communicate, receive feedback and, thus, form stronger ties of communication. Create a synchronous activity with Chat, asking each student to bring an example application or text related to the content. Facilitate the meeting and propose that everyone share their opinions on the material presented by their colleagues. It is important that you carry out a self-assessment on the application of the strategy in order to verify the need, or not, of changes in the action.*"

Therefore, from the 228 PS, these were applied by professors and monitors in two graduate subjects and then they were invited to answer a questionnaire. The evaluation of these data is presented below.

4 Methodology

The methodology of this study is qualitative. This choice is justified as a result of the research object involving the Socio-affective Scenarios that are inferred in the ROODA, expressed subjectively through the exchange of messages, texts and the relationship between the participants.

According to Creswell and Creswell [13], studies that cover socially constructed knowledge tend to present open questions, situations in which the qualitative approach is the most indicated.

In this context, qualitative data are examined based on a Content Analysis according to Bardin's precepts [14]. For the author, there are three phases for organizing an interpretative approach, which are: (1) *pre-analysis*, (2) *exploration of the material* and (3) *treatment of results*.

In the initial phase (1) the *pre-analysis*, the material is organized, the documents are chosen, hypotheses are formulated and the indicators that will guide the final interpretation are elaborated. It is necessary to observe some rules: a) Exhaustiveness: exhausting the whole subject without omitting any part; b) Representativeness: worrying about samples that represent the universe; c) Homogeneity: collect data using the same techniques and similar individuals; d) Pertinence: adapting the documents to the research objectives and; e) Exclusivity: classifying an element in only one category. Next, in the phase of (2) *exploration of the material*, the data are encoded; process by which transformation and aggregation into recording units (words, themes or other units) occurs, with subsequent categorization. In the last phase, (3) the *treatment of results* includes codification and inference. The researcher needs to return to the theoretical framework and base the analyzes trying to give meaning to the interpretation.

Thus, the analysis of the use of PS by professors and monitors was divided into two parts: 1) application and; 2) evaluation. In the first, the researcher sent the PS manually to the professors and monitors in two graduate subjects, in the distance modality, which took place in the 1st semester of 2021 and 1st semester of 2022 in a Brazilian Public University. The subjects were focused on the application of digital technologies in the teaching and learning processes. They lasted 15 weeks and one of them had 3 professors and 2 monitors and the other had 3 professors and 1 monitor.

The professors had the function of choosing, weekly, one of the 6 PS based on Socio-affective Scenarios per student and applying in ROODA, as well as correcting their activities. The monitors asked each student, in the Logbook tool, every week if he had performed the action of the strategy requested by the professor. That way, if the student answered, a conversation was started. In addition, the monitors also got in touch with the professor to understand what he had asked for and which tool was used, then they would check if the student had really done what was requested.

Thus, of the total value of 228 PS available, 83 strategies were used in both subjects. It is important to note that the PS are in Brazilian Portuguese, as this is a study specifically applied in the country.

In the second part, at the end of the school year, the 6 professors and the 3 monitors were invited to answer a questionnaire. The data obtained were examined, and two categories were created based on Bardin [14]:

• Category I - Profile of participants: professors and monitors.

• Category II - Analysis and evaluation of PS based on socio-affective Scenarios by professors and monitors.

Thus, in the next section these categories are analyzed.

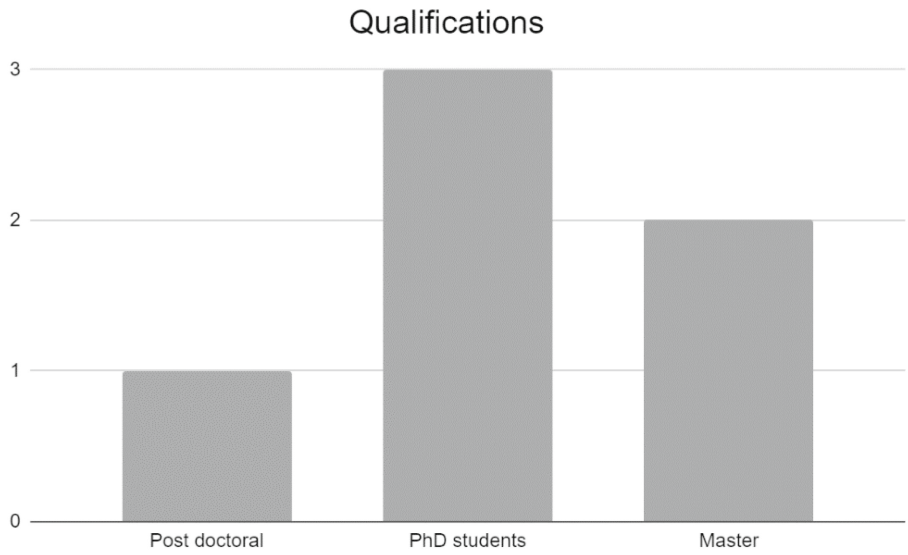
5 Results

The questionnaire (https://drive.google.com/file/d/1cbsiXwBY7YBC_KlRWwkafX_rummaJ4-G/view?usp=share_link) applied to the 6 professors and 3 monitors was the same. It was prepared based on Maria [11] and Sonego [12], and consists of 26 questions, 1 of which is multiple choice; on the respondent's sex and the other 25 dissertations. The first three questions were related to the profile of the participants.

5.1 Category I - Profile of Participants: Professors and Monitors

For the participant to be able to answer the questionnaire, it was necessary to accept the terms of the research. In our study, all professors and monitors agreed to collaborate. In this context, the questions asked in relation to the profile were three, namely: 1) What is your sex?, 2) How old are you? and, 3) What is your qualification?.

Regarding the professors' answers, 6 were obtained, 100% were female and had an average age of 38 years. Qualifications consisted mostly of doctoral students (n = 3), followed by masters (n = 2) and post doctoral (n = 1), as can be seen in Graph 1.



Graph 1. Profile of the professors. Source: created by the authors (2022).

Thus, as shown in Graph 1, the profile points to subjects with academic experience, as it consists of an undergraduate degree. On the other hand, the three monitors were female, with an average age of 25 years, one of them being a graduate and the other two graduates.

Subsequently, the other questions were related to the analysis and evaluation of the PS by the professors and monitors, described below.

5.2 Category II - Analysis and Evaluation of PS Based on Socio-Affective Scenarios by Professors and Monitors

The 23 questions out of a total of 26 were related to the experience that the 6 professors and 3 monitors had about the use of PS. The questions were about: the positive and negative points in the application of the strategies, the students' perception regarding the performance of activities aimed at Socio-affective aspects, the students' preference for the use of some tool, the professors' opinion about whether the students liked or disliked the use of PS, the importance of strategies in a teaching activity, the view of professors and monitors about the PS contributing or not to intensifying the interaction in the VLE and the suggestions for changes.

To maintain the anonymity of the participants, the letter "P" was used during the analysis, followed by a number for the professors and the letter "M" and a number for the monitors. It should be noted that the answers taken from the questionnaire were not altered in their text.

In this scenario, as a positive point in the application of PS, monitor M1 signaled that "*Students interact more significantly and recurrently with the team. The socio-affective results allow the professor to be more attentive to the student's needs and apply different* *strategies than just a generic email that is often ignored. I believe that this tool has made the student experience more welcoming*". This statement is consistent with the authors Barvinski et al. [15] in which PS can expand the possibilities of innovation and use of technological resources in VLE. As a negative point, M1 mentioned "*I believe that carrying out the strategies every week may have overloaded the students a little, because the discipline itself has 'complex' activities, considering that the student needs to explore tools that in some cases have never had contact, with deadlines to be carried out each new week*".

With regard to social and affective aspects, it sought to find out if the professors and monitors observed that the students perceived that activities were carried out to meet these two elements. M1 mentioned: "*When applying the PS, it was often mentioned that the proposed actions were important to interact with colleagues and share learning. I believe that perhaps they did not relate to the term 'socio-affective', but they understood the importance and our intention of bringing them closer to colleagues and exchanging learning*". This report is very important, as the monitor mentions that the students may not have related the term socio-affective, but they understood that it was essential to get closer to colleagues and exchanges in the VLE.

Professors and monitors were asked about their students' preference for using a tool. The answers were diverse, M1, P3 and M2 observed a lot of use of the "Logbook and Web Portfolio". P1 and P2 scored that their students liked "Contacts". P4 and P5 wrote "Logbook and Contacts". P6 and M3 noticed adherence to "Contacts and Web Portfolio". Thus, there is no consensus on a single tool.

In relation to the opinion of the professors and monitors about the students whether they liked or not the application of the PE, P3 reported: "*They carry out the activities in the tools they liked, in the other tools they did not*". On the other hand, M2 wrote "*After applying the strategies, we always tried to talk to find out how they received them, and the response was always positive*".

In the view of all professors and monitors, the application of PS in the subject is important, as M1 pointed out that: "*The class became more united, students were able to interact more, ask for help when necessary and felt more welcomed. I believe that this socio-affective analysis and the application of strategies allowed the student to see beyond the activities that are delivered or not*". P2 pointed out that: "*Strategies can guide the professor's action, helping him to receive recommendation on how to act to help the student according to his socio-affective status*". For P3 "*They started to look more at the work and posts of their colleagues*". P4 signaled: "*It is important to encourage students*" and P5 considered that the PS "*Contributed to interest and motivation*". M2 visualized "*Contribution to student work collaborating with each other, even if the work was individual*". These answers are in accordance with the perspectives of PS according to Barvinski [10], in which they encourage collaboration, cooperation, interaction and student participation. In addition, PS contributes to advising the teaching and learning process, expanding possibilities for both professors and students, building knowledge and sharing information.

In this context, it sought to know whether the professors thought that the strategies contributed to intensifying the interaction between the participants, or not. P3: "*I noticed a greater commitment to expressing and interacting with colleagues, when reinforced* *that this was important and good for everyone's learning*". This passage is very relevant, because the professors should have the knowledge that in addition to applying the PS, it was essential to emphasize how the interaction and exchanges with others were fundamental for the teaching and learning process.

The main suggestion for improvement was in relation to "*The strategies that use the Chat tools had no return, I suggest checking whether the approach should be maintained or changed*" (M2). It is important to note that to use this tool, users must be online simultaneously, which can make communication between the parties difficult.

Therefore, from the analysis of the answers obtained in the questionnaire, the main points were raised:

- The creation of a tool so that it is possible to automatically recommend PS.
- The relevance of, when analyzing a student with the "drop out" Scenario (never accessed ROODA and did not cancel the subject), regardless of the chosen PS, send a notice to him in the personal email, in order to verify if he returned to subject.
- The importance of the professors and monitors considering the context, the student's outlined profile and the other elements present in the strategies, such as technological resources and methods.
- The relevance of the PS, because in the view of the professors and monitors, they served to intensify the interaction and the exchanges in the VLE.
- The role of the professors and monitors of personalized accompaniment was fundamental for the students.

In this way, from the answers and main points raised, it was possible to carry out the improvement of the PS.

6 Conclusions

In Distance Education, the physical distance between the participants makes their relationships unique. In this way, the ways of knowing the other, communicating and acting in a Virtual Learning Environment are elements of analysis for a continuous qualification. In this way, considering the needs of each student, when applying Pedagogical Strategies (PS) can be an instrument to support the professor, making it possible to personalize teaching and learning.

The study analyzed 228 PS, being possible to apply 83 of them, which were considered the most relevant and corresponded to the Socio-affective profile of the classes. Subsequently, the 6 professors and 3 monitors who used the strategies answered a questionnaire about their experience. The results point to a more significant and recurrent interaction with the pedagogical team, the possibility for the professor to be attentive to the Socio-affective needs of their students; making them more welcoming and the intensification of interactions in the VLE through the application of PS. In addition, students began to see more of their colleagues' work and posts, they became more united; increasing interest and motivation.

As contributions of this work, the 228 elaborated PSs and the strategy analysis questionnaire are available for use by other professors, manually.

As limitations of the present study, not all strategies were applied and evaluated, so it is possible that there are suggestions for changes in some of them.

The possibility of future research is related to the creation of a tool that makes the automatic recommendation of the Socio-affective Scenarios and indicates their PS to the professors.

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Online Asynchronous Mathematics Interactions: Similarities and Differences for Teachers and Students

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Abstract. The work is framed in the context of online interactions made by teachers in training and freshmen students. Various literary references discuss the students' difficulties in mathematics in the transition from secondary school to university. Here we experience the need of promoting critical thinking, to let students be able to make reasoned decisions or about what to do and think. So, it becomes necessary to investigate how the use of online resources is useful for this purpose. We have designed particular online resources, the Moodle workshop, whose aim is to develop the mathematical thinking of those who participate by leveraging the valuable contribution of the feedback that students can receive from peers and that of their own work in reviewing peer products. In such a way the students have the opportunity to reflect on representations and problem solving that differ from their own. Specific aspects of online resources, such as the Plasticity and the Technological Multi-modality are shown in the context of online teacher training, precisely where these terms were coined. The aim is to investigate whether such constructs also take place in different contexts, such as precisely that of university students in asynchronous conversations, always linked to collaborative learning moments. For this reason, university students' online interactions have been explored in order to understand how these constructs could contribute to the improvement of students' learning. First considerations and some findings about the use of the considered aspects have been provided.

Keywords: Asynchronous mathematics interactions · plasticity · technological multimodality

1 Introduction

Over the last few years, there have been major changes in technology that have obviously had a major impact on how teachers plan their activities.

Research in education, and in particular in mathematics education, is struggling to keep up with technological innovation. This view is well described by Borba et al. (2016) that point out the sequential steps of technological evolution. In particular, the development of online communication and collaboration technology has had an impact

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on the way students communicate. This has led to the emergence of new aspects to be considered in research that turned to study the effectiveness of collaborative learning Borba et al. 2016.

At this stage, the need for research concerning design science is strongly affirmed, in order to exploit technologies for improving teaching and learning processes and to produce proposals for the classroom (Lesh and Sriraram, 2010):

"*Researchers should DESIGN for Power, Sharability and Reusability; They don't just TEST for It. Survival of the useful is a main law that determines the continuing existence of innovative programs and curriculum materials; and, usefulness usually involves going beyond being powerful (in a specific situation and for a specific purposes) to also be sharable (with other people) and re-usable (in other situations)*" (p. 126).

What mathematics concerns, some recent literature goes in this direction (Aldon et al., 2017; Faggiano et al., 2017; Drijvers et al., 2010; Albano & Ferrari, 2008). In this continuing ongoing development of the technologies, teachers should be able to put into practice the design science as part of their usual professional practice and to become researchers in educational design, instead of being only recipients of the research results Laurillard, 2012. Indeed, the most recent developments in technology have offered new communication interfaces, such as learning management systems and e-learning platforms used both for hybrid training courses and for totally online courses, such as MOOCs (Massive Open Online Courses) aimed at both students, usually university students, and teachers. Also Llinares and Olivero (2008) underline that the use of new communication tools (forums, chats, …) plays a central role in the generation of communities of learning, which are formed by people who engage in a process of collective learning. These studies were taken up by Bardelle and Di Martino (2012) who conducted a theoretical exploration of the potential of online environments in helping students to overcome the mathematical difficulties in the transition from secondary school to university.

2 Theoretical Background

MOOCs are courses delivered entirely online and devoted to a massive number of participants. They are offered openly to learners through the web, and appear as dynamic and diversified learning spaces with varying factors, such as flexible time frames, a massive number of students from different demographic areas, motivation to continue learning, and opportunities for designers to implement novel pedagogies including collaborative learning activities (Manathunga et al. 2017). Metcalfe (2007) studied that in MOOCs the so-called "Network Effect"' occurs. This effect postulates that the value of a product or service increases with the number of people using it. In MOOCs networked learning is a process of collaborative meaning making and competence building through mutual support and interaction amongst learners Goodyear et al. 2004. Even in unstructured spaces for learning, such as social media, it has been observed that learners, especially teachers, often enter such online spaces to find professional learning opportunities (Anderson 2020). Teachers find communities where they can participate in critical reflection on their practices, learn about new contents or methods, access experts outside their personal network, and develop their teaching identity through discussion Macia and Garcia 2016.

Since 2015, for five years, the Department of Mathematics “G. Peano” of the University of Turin has been running the MathMOOCUniTo project. It was a project aimed to design and deliver MOOCs for Italian mathematics in-service teachers, to increase their professional competencies and improve their classroom practices.

In the MOOCs of the MathMOOCUniTo project there was no moderator in the discussions and the will to establish the threads often leaked out, though it is very difficult for them to take shape in a broad and articulated manner. The threads tend to split into different groups, which are formed and split locally and for a certain period of time, but generally, they contribute to giving all learners the sense of common participation in one unitary event, precisely the MOOC. In such a contest, Taranto et al. (2017) define a characteristic aspect, the *plasticity* that is the ability of an online user to be able to adapt to discussions that precisely take place in the online mode, thus entering the thread of discourse without having previously taken part in the conversation. Therefore, plasticity makes it possible to adapt to various situations in different groups and times, within a community that preserves its global unity. This unity consists of the collaborative sharing of what happens, even if the active participation converges on more than one local theme.

The other characteristic aspect of MOOCs aimed at mathematics teachers was the *technological multimodality*: fragments from the history of web communication (from web 1.0 on) coexist and complement each other, and trainees themselves used these interacting systems of different technological ages (Taranto et al., 2017). It is something similar to the multimodal interactions that take place in the classroom thanks to the activation of different registers (Duval, 2017).

3 Motivation and Research Question

In this paper, we are interested in investigating how the asynchronous communication tools and the possible collaboration that takes place online could improve university students' learning. As we will describe in more detail in the next section, we have designed online resources that provide for asynchronous interaction between students (Sabena et al., 2020, Pierri, 2020). Students thus have the opportunity to check their learning levels, plan and implement, in interaction with the teacher and classmates, the strategies necessary to achieve the given learning objectives. In particular, we are interested in investigating whether the two specific qualities that have emerged in MOOCs for teachers, namely plasticity and technological multi-modality, also emerge when students interact online using digital resources. Therefore, the research question guiding the study is the following: *To what extent and how is it possible to delineate the presence of plasticity and technological multi-modality in asynchronous learning by university students?*

This work is in line with one of the four themes on which the UMI DIGiMATH group is working.

DIGiMATH group (https://sites.google.com/unisa.it/digimath/home-page) aims to reflect on the use of technology in university teaching by aiming to focus on problems encountered by students and observed by teachers.

4 Methodology and Data Source

With the aim of identifying and analyzing examples of plasticity and technological multimodality, we begin by showing examples of their application in the context in which these terms were coined, namely in MOOCs aimed at mathematics teachers.

We will consider the Geometry MOOC, the first of the MOOCs delivered in the MathMOOCUniTO project. That MOOC proposed to teachers some mathematical topics that are generally hard for students. Among them, we chose to consider the concept of angle, which is covered in a MOOC module that lasts two weeks, starting from the third week of the MOOC (the MOOC, in all, lasted 10 weeks). We chose to consider the communication message boards set up during these weeks and follow the interactions in which the same teacher (N.C., who teaches in the higher secondary school) is always involved, to see how the two concepts of plasticity and technological multimodality are present and articulated in the interactions in which N.C. is involved, along with other MOOC participants. We underline that three different types of communication message boards have been set up in the MOOC (forum, tricider and padlet). The MOOC is delivered through a platform based on Moodle. The forum is a platform already integrated into it; the other two have been included as extensions of Moodle itself. The specificities of each will be described directly in the data analysis.

Concerning the example provided for the use of online workshops and forums at university level, they constitute a support to a traditional f2f course of Geometry, Algebra and Logic (GAL) for freshmen students in Computer Engineering (second term).

The online workshops are focused on peer review processes implemented by using the “workshop module” of the web-based platform Moodle, followed by a structured feedback by the teacher. This resource allows students, on the one hand, to upload the solution of a specific task and, on the other hand, the automatic and anonymous redistribution of the productions, to be assessed by other students, related to a specific topic of the course. Assessment is guided by specific criteria established by the teacher. The submission consists of plain text and optional attached files including the students’ answer with respect to a specific topic assigned by the teacher.

The content of the GAL course mainly concerns linear algebra, whose learning difficulties are well known. The course foresees two written examination tests, one mid-term and one final, that are prerequisite to access the oral exams. Four online workshops have been submitted, two before each of the written tests, conceived as summary exercises in view of the test to be done. For each session, about 40 exercises have been prepared by considering the different tasks submitted to the exams session. Each of them has been distributed to groups of 3 or 4 students randomly chosen. In fact, there is no assurance that a student would not receive the same problem she solved, but we can assume that this is the case for two reasons: first, the number of problems is very high; second, the problems chosen have more than one solution path, so even if a student was asked to evaluate the same problem she solved, there was a chance that her peers would have solved it differently. In the following section, we focus our attention on the online resources put into action during the first part of the course and related to the Matrices topics. That is because we have obtained high participation of the students both in the threads of forums discussion and in the participation in the workshop. In particular, in the forum discussion we could investigate the presence of the plasticity, while the presence of the technological multimodality is more evident in the online workshop where, in the review phase, the students could upload some additional materials for giving more details about the provided feedback.

5 Findings

5.1 Example of Plasticity and Technological Multi-Modality in the MOOC

We show some of the interactions that mathematics teachers have initiated on three different communication message boards made available in the Geometry MOOC, related to the mathematical topic angle. These examples, focused on the same teacher, N.C., show how he showed both plasticity and technological multi-modality in dealing with the topic of the angle.

The first communication message board is the forum, proposed immediately after the first activity presented to teachers. The activity proposed to teachers, taken from the m@t.abel repository, is "The Clock" (http://www.scuolavalore.indire.it/nuove_risorse/lorologio/). It aims to construct the meaning of angle and arch, in order to enable the student to grasp their distinction and application. In particular, students are invited to measure angles of various sizes using different methods; to express and represent the results of angle measurements; and to solve problems using the geometric properties of figures, including by resorting to material models and simple deductions.

The forum asks teachers to share their ideas and/or teaching experiences related to the topics covered in this activity. It collects 31 discussions, each of them with from 1 to 21 response replicas. When reporting teachers' posts, we will specify the day they were written and the time (this is data that the forum by default carries).

N.C. writes [02/11/2015, 10:02]:

The equality of angles for Euclid derives from the superposition and coincidence of angles, not from measuring with a protractor. Yet for my boys, after the two-year period, an angle is only right 'when it is 90°'. The defining and definitive property then becomes the measurement, not the relationship and comparison with other angles.

M.L.C., a teachers from the higher secondary school, answers [03/11/2015, 15:36]:

I am also struggling, in the two-year secondary school, to get students to abandon the concept of measurement in order to talk about intrinsic properties […].

Then, S.S. from the primary school writes [06/11/2015, 19:15]:

During a geometry workshop on paper folding in a fifth-grade primary school class, I talked to the children about angles by folding a sheet of paper, and in particular about right angles. It was very interesting to observe that, as I had forced the children to make an initial fold 'at random' and not an axis of symmetry of the sheet they were holding, at the next superimposition of the fold on itself and subsequent reopening, the sheet of paper was divided into 4 parts that had a different shape. One child protested: 'but how! why do you say that they are 4 equal angles?? they came out different to me!'. It had been a nice way of talking about angles, which came back to me when I read the form in question. In fact, in the geometry of folded paper, we disregard the measurement, proceeding with the division into parts. Older kids don't commit such naivety anymore, but the perfection of right angles in 2 folds (possibly a bit precise... But it's the thought that counts!) remains fascinating to me.

The latest entry in this discussion is by S.B., a lower secondary school teacher [24/11/2015, 19:23]:

I confirm that even in middle school, the problem of 'measurement' is predominant at first. We have to get the children used to seeing, understanding, the properties of 'objects' and their relationships independently of 'numbers'. On the question of the 90° right angle (which they already know from primary school), with my sixth-grade students, I try on the one hand to reinforce the concept of angle (always a difficult knot). On the other I start with a sheet of paper (not squared), a half-line and the round angle that can be obtained (visualised mentally), and then begin to fold it in half and 'discover' the flat angle and then the right angle. I reserve the measurement of amplitude and its unit of measurement (with historical meanings) for a later date.

Already from these first interventions it is possible to grasp the plasticity. Indeed, we note that N.C. had started his reflections on 02/11/20215 and the other teachers who join this discussion do so on different days and also far away from 02/11/2015. However, although there is this "wide" temporal distance (the last reply is dated 24/11/2015), the same common thread remains: we talk about the angle and share experiences on the teaching of this concept at various school levels, from primary school to higher secondary school.

Next, the MOOC module goes on to offer two more activities. One is aimed at lower secondary school students, entitled "Moving with Angles". Again having as a basic concept that of the angle, the activity allows working on moving in a certain direction defined by an angle; on moving on maps and proposes an approach to the concept of similarity. The other activity, entitled "From Astronomy to Trigonometry", is aimed at higher secondary school students. It focuses on the construction of angles, also making use of dynamic geometry software, and then shows applications of the concept of angle, referring to Eratosthenes and his calculations to measure the earth's radius.

The communication message board setted up by the trainers is the Tricider. In it it is possible to propose an idea, to put a "like" or "dislike" to that idea, to comment for or against that idea. Here, the teachers were invited to answer at least one of the following questions:

Which path(s) are you used to present to your students in order to construct the meaning of angle/arch?

Which activities with technologies do you take into account to facilitate the learning of the angle/arch concept?

The Tricider collects 112 discussions, each of them with from 0 to 62 response replicas.

N.C. proposes a video in which the game of billiards is illustrated (Fig. 1) to allow the students to become familiar with the concept of angle (or to show a playful application of it). In particular, he writes:

I think a Hi-Tec activity like this one of the billiard laser sight can be sooooo interesting for the kids: https://www.youtube.com/watch?v=l2bzAmysjc8

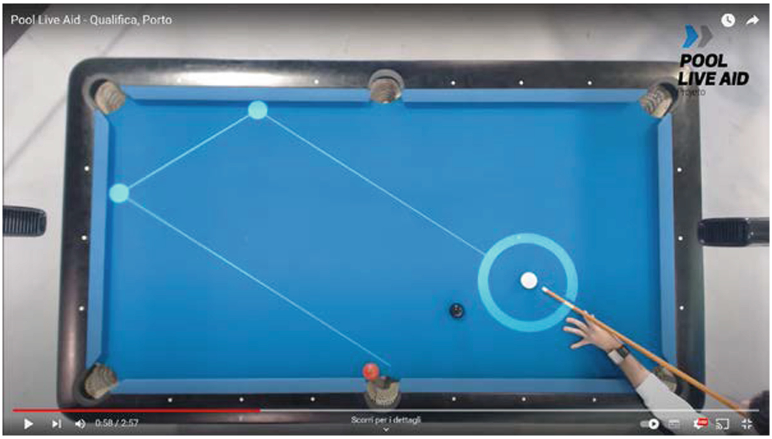

Fig. 1. Screen taken from the video suggested by N.C. in the Tricider

N.C. receives 24 likes and 14 comments in response to his post. Many expressed appreciation for the video, writing for example: "*Very interesting video! to be shown several times both for the corners and for the elastic collisions*". Others respond with similar proposals, for example M.T. writes: "*to introduce the activity of billiards it is also nice "Donald's billiard" from "Donald and the matemagic" (I guess you already know it, but… You never know;-)* https://www.youtube. *Com/ watch? v = nm3yhQJnxiQ hide"*. We thus witness the coexistence of text and links, a first example of technological multimodality, which refer to external sources, such as the videos that become the subjects of the teachers' speeches.

In the following week, other three activities have been presented. One is entitled "Watches, pinwheels and skaters" and is addressed to the lower secondary school. It provides work on the concept of rotation, with activities to be done first with paper and drawing tools, then also with dynamic geometry software taking into account examples from the reality. The second activity, entitled "The Christmas show", designed for students in the first two years of higher secondary school, proposes a real problem to be solved with the use of dynamic geometry software. In fact, it is asked to determine how to position a bull's-eye with a 35° cone of light so that all and only one stage is illuminated. The latest activity, again for higher secondary school students, entitled "How steep will it be?", aims to contextualize the concept of slope in a real situation: an excursion to the mountains.

The last communication message board considered is the padlet, a space where it is possible your own post, containing text and also upload files of various kinds (.pdf, word, excel, videos, photos,…). Teachers are asked to answer at least one of the three following questions:

1. How do you usually introduce this conceptual node (the angle) and how do you recall the different concepts?
2. In the light of the proposals in the training courses you have seen, argue whether, how much and why, in your opinion, an approach linked to real-life situations can improve learning?
3. On the basis of your experience, discuss how much and how technologies can facilitate your teaching action in making your students overcome misconceptions linked to the angle.

N.C. tells how he introduced the concept of angle by linking it to the concept of curves in the plane, by means of an activity prepared together with his English colleague, using a famous game "Angry birds" (Fig. 2):

Regarding the concept of angle, I propose a possible approach to that between curves in the plane, i.e. the angle between straight lines (tangents to curves). The Clil-style activity, developed some time ago together with my English colleague, used a well-known video game: Angry Birds. Here are the links to the pdf and the GeogebraBook, should you be interested.

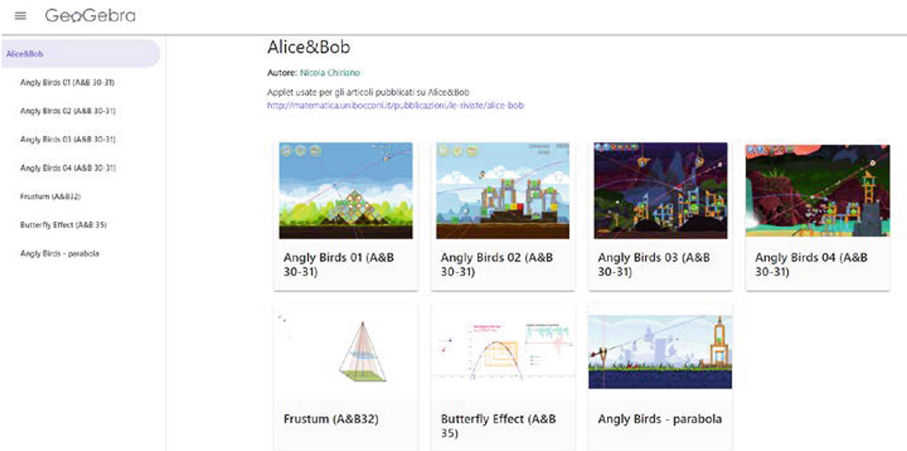

Fig. 2. Screen of the GeoGebra book indicated by N.C. in the Padlet

Let's see again how text and references to external resources (in this case a GeoGebra book) coexist and complement each other in winning, inserting themselves in the construct of technological multimodality.

5.2 Example of online resources for freshmen students

The Use of the Forum

We show some of the interactions among teachers and freshmen students by using a Forum online in a Geometry, Algebra and Logic course. The teacher opens a discussion on the forum about the calculus of an inverse matrix (Fig. 3).

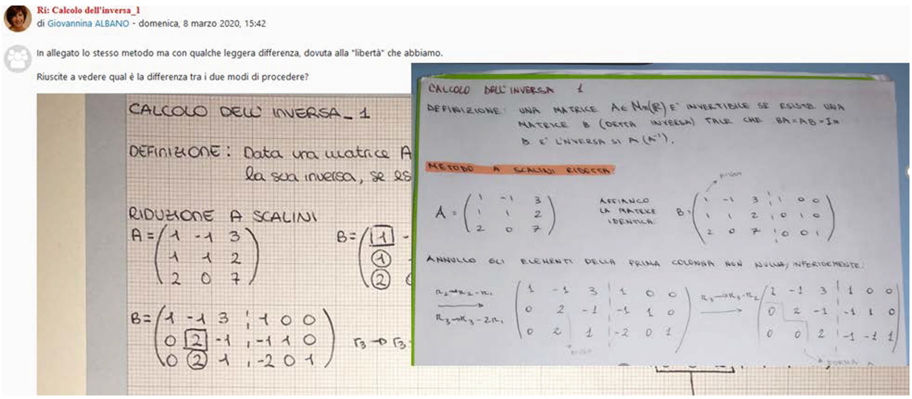

Fig. 3. Forum Discussion

She uploaded on the forum two different resolution paths and asked the students [08/03/2020, 15:42]:

Here are two solving methods with some slight differences due to the freedom of unfolding we have. can you see the difference?.

S1, a student that participate to the discussion, answers [11/03/2020, 12:40]:

To reduce to reduced steps in the first method we first normalized the pivots by making them 1, then canceled the elements above them. In the second method we first canceled the elements above the pivots and then normalized them. The result remains unchanged [...].

Then, S2 student writes [11/03/2020, 14:18]:

I found some computational errors in reference to the second resolution where the algebraic complement takes place […].

We can thus see how student S1 refers to appropriate theoretical recalls, while S2's observation is purely computational. So, the teacher resumed S2's observation by pointing out that it is important to focus on the process and not just the end result. He writes [11/03/2020, 16:36]:

However, if you look closely at the reported calculation of a'_3,1 (i.e., the algebraic complement of the element in position (3,1) of A) , correctly the result -5 is reported. The calculation of the determinant of A equal to 4 is also reported correctly.

So actually putting the two together and the definition of the addition of A and the inverse theorem, the result is correct because we have that the value in position (1,3) of the inverse of A must equal the quotient between the algebraic complement of a_3,1 and det A. Therefore, if we were to evaluate what was written, we would say that there was an error of distraction or transcription [...].

So, from these first interventions it is possible to grasp the construct of plasticity. Indeed, the teacher started his reflections on a task made by a student different from S1 and S2 that joined this discussion.

The Use of the Workshop

The workshop aims to make students responsible for both their own learning process and that of their peers. The intent of this online resource is to promote student development during a learning process through active engagement of the student in two specific phases. Active engagement is more critical in online settings because students are expected to self-regulate and take primary responsibility for their learning.

In the first part of the peer assessment activity, it is asked to the student e to upload the resolution of specific problems set by the teacher. After automatically and anonymously distributing the different resolutions, ensuring that the individual student does not receive his or her own unfolding, the student is called to give feedbacks about the resolution of his peer by resorting to evaluation criteria appropriately prepared by the teacher in the workshop design phase.

This provided them with an opportunity to expand their thinking as they composed or received critical comments from their peers. It also exposed students to diverse possibilities as they reviewed peers' thinking and/or artifacts. These elements of peer–peer feedback were also characterized by reflective articulations and meaning making. Following we summarize some kinds of feedbacks that students send to their peers:

– very articulated feedback supported by theoretical argument;
– attention to formal aspect related to the use of literate register;
– affect feedback s;
– feedback related to the communication

When the performance is not sufficient at all, it seems that students are not able to articulate punctual feedback. Then they simply attach a file containing a worked-out problem. Let's see how the references to external resources (in this case a.pdf file) allow us to consider the construct of technological multimodality. In this way, the use of external structures enables learners to analyze their own approach to problems, thereby identifying both strengths and problems related to their own approach, a result that cannot always be achieved by just writing down what to correct.

5.3 Similarities and differences among the two contexts

Comparing the two experiences described above, similarities and differences emerge which we outline here. A similarity that immediately emerges is the place where the asynchronous communications take place: via Moodle communication message boards.

The samples under examination are certainly different: in the MOOC we have trainee teachers and the others are university students. Both groups work on a single mathematical topic: angles for teachers and matrices for students. For both groups, there are resources to consult upstream: for teachers, these are proposed activities presented in the MOOCs, for students, in-person lectures. However, the two groups approach the math topics with different instructions. Teachers are invited to share their teaching practices on this concept and to reflect on what misconceptions it brings. Students are invited to reflect on solving the same exercise by applying different strategies. Moreover, teachers can like and add themselves to the discussion thread with nested replies. They are free to interact when and with whom they want. Students do not freely choose which peers to interact with. It is the workshop that assigns them automatically and in a certain quantity. Students can write suggestions and leave comments.

6 Conclusion

Our research objective was to understand to what extent and how the constructs of the plasticity and technological multimodality can be detected in the asynchronous communications of university students. In our view, *plasticity* seems to be less present than it appears in MOOCs.

Indeed, the workshop is an environment that fosters interactions, but at the same time constrains them both at the level of topics and at the level of confrontation with peers.

- at the level of topics (if the workshop is about solving matrices by means of the normalization criterion, it might not be meaningful to speak of determinant)
- at the level of confrontation with peers (it is not the student who decides with whom to interact, but it is the system that automatically assigns peers with whom to discuss).

Technological multimodality emerges somewhat. In fact, when students cannot fully interact on the forum, they upload.pdfs. This happens, probably, because it is easier to write the mathematical part on paper. The forum does not have an advanced mathematical text editor. Similarly, teachers, when they want to share reflections or strategies that "are easier to show than tell", wrap themselves in links to external resources (e.g. videos, GeoGebra book, etc.). From the verbal register, they move on to the graphic, the pictorial, the video! Therefore, a multimodality of resources supports them (students and teachers) in talking about mathematics.

In this sense, we believe that technological multimodality is a way of using online resources that students put into action contributing to the improvement of their learning.

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Engaging Mathematics Teachers as Designers of Digital Educational Resources to Foster Their Awareness in Counsel

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Abstract. The paper describes a project concerning the design and implementation of an educational path devoted to in-service lower secondary school teachers (ISTs). The project aims to increase the ISTs' technological skills as well as their awareness, by involving them in designing digital educational resources for their students. Moreover, we are interested in the participants' perceived impact of the educational path on their professional development. Our analysis, carried out according to a case study methodology, allowed us to highlight a change of perspective and the increase of the awareness of most of the ISTs, who shifted from the occasional use of simple GeoGebra files (mainly created by others) to the potential plan to autonomously producing GeoGebra applets with different educational goals. Moreover, most ISTs perceived an improvement in their professional development in terms of technological and didactical skills, fostered by their engagement and communication within the cooperative activities carried out in remote learning.

Keywords: teachers as designers · teachers' awareness · digital resources

1 Introduction

Recent studies in mathematics education have focused on the teachers' engagement in the design of didactical resources and, in particular, tasks [1, 2]. According to [3], the partnership between teachers and researchers in resource design processes could significantly improve teaching and learning practices in mathematics, under the condition that the principles of design are shared and the effective integration between the task design and the pedagogical philosophy is taken into account. It has been recognized that the work with tasks and, in particular, the engagement in the design process of digital resources should foster the teachers' professional development, in terms of both mathematical content knowledge and pedagogical knowledge [4]. Moreover, collaborative didactical design should favor the teachers' metacognitive reflection on their own didactical practice, as well as their understanding of methodological aspects and benefits of cooperative learning by direct experience [5]. Indeed, through working on mathematical tasks, teachers could "*engage in mathematical thinking* […]*, reflect on the experience of*

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doing mathematics-related tasks […]*, consider implications for teaching*" [6, pp. 207–208]. When the design process of tasks or resources envisages the use of digital tools, some further considerations are needed. In this case, according to [3], it is necessary to take into account *what* to design, *i.e.* the object of the design (a task/a sequence of tasks, a self-assessment/explorative/remedial activity, …) and possibly the students' difficulties that it should allow to overcome; *what tools* are necessary (manipulative artifacts, virtual artifacts, specific technological tools, …); and *under what conditions* the design process could be carried out, *i.e.* how the resource should be used to promote the students' learning (individual use in the classroom, working in groups, …). Moreover, also the constraints and affordances that the technology offers with respect to traditional environments should be carefully considered.

This paper sets in that stream of studies and should contribute to investigating the perceived effects of engagement in the design resource process for teachers' professional development in terms of metacognitive practices [7, 8]. More in detail, the educational path is designed to improve the participants' *awareness-in-counsel* (*i.e.* the awareness needed to be a "real teacher" [8, p. 243]) about the potentialities of the integration of technological tools and resources in their teaching to foster students' learning.

2 Theoretical Framework

The main component of our theoretical framework is the notion of *awareness* as described by Mason [8]. According to the author, "*to be a real teacher involves the refinement and development of a complex of awarenesses on three levels*". Mason identifies the following levels of awareness:

a. the *awareness-in-action,* which consists in the power of acting in the world, with a focus of attention that is typically implicit; for what concerns mathematics, it consists in the actions of counting, ordering, classifying, relating, and so on;
b. the *awareness-in-discipline,* which is the awareness of awareness-in-action and arises when the focus of attention of the individual becomes explicit, while he is acting in the world. For example, "*mathematics as a discipline arises when we become aware of awarenesses-in-action such as those constituting counting, ordering, classifying and relating and start to formalize these in the language of algebra and geometry*" [8, p. 258];
c. the *awareness-in-counsel,* which is the awareness of awareness-in-discipline, *i.e.,* the awareness needed to be sensitive to what others require in order to build their awarenesses-in-action and-in-discipline.

In particular, the awareness-in-discipline is the awareness of the expert in a specific subject, for example, the awareness of the mathematician. But teachers need something more: it is just becoming aware of the awareness-in-discipline that enables them to teach their subject effectively.

Indeed, the teacher has a crucial role in making the students orient their attention like an expert in the discipline. This can be pursued by creating conditions and learning environments in which students could experience suitable *shifts of attention* [8], allowing them to focus on some aspects rather than others and to become aware of specific mathematical facts.

In this sense, the educational path that we devoted to our ISTs aimed at developing their awareness-in-counsel about the didactical potentialities of technological tools, specifically in provoking *shifts of attention* in their students.

3 Research Context and Methodology

The educational program involved 114 ISTs of lower secondary schools of Marche region (Italy) and was carried out through the conference platform Zoom. According to the constraints imposed by the Regional School Office of Marche, the educational path lasted two months, from May to July 2021. The participants were exposed to 4 plenary lectures of two hours and a half, and to 4 laboratory sessions of two hours. Moreover, the course also envisaged 12 h of autonomous practice by the ISTs aimed at allowing them to create their final project work.

The plenary lectures, conducted by 4 faculty members including the authors of this paper, have been devoted to giving an overview of the following issues: students' difficulties and misconceptions in Mathematics; the potential of the software GeoGebra and its community; Euclidean geometry of the plane and three-dimensional space with GeoGebra. During these lectures, the opportunities offered by the software GeoGebra and its functionalities (drag and drop, checkboxes, input fields, …) to support the students' learning have been explored. Indeed, some GeoGebra applets with different educational goals (visualization, exploration, self-assessment, …) have been shown to the ISTs.

During the laboratory sessions, conducted by the same teachers who taught the plenary lectures supported by other 4 teachers, the ISTs worked in small groups of 4–5 people and interacted through the breakout rooms in the Zoom platform. In the first two laboratory sessions, the ISTs were asked to construct their first GeoGebra applet by following some accurate guiding instructions, so that they gradually become familiar with the software. The instructions allowed them to construct either a mathematical object (e.g., the construction of an equilateral triangle with "a ruler and a compass") or a didactical part aimed at inducing a meaningful exploration and learning of the mathematical object itself. In the subsequent meetings, the ISTs have been invited to discuss the students' typical difficulties and misconceptions about a specific mathematical proposed topic or object and, consequently, to design and implement GeoGebra applets aimed to favor the overcoming of these hardships. The tutors were available to support them during and between the sessions. The ISTs jointly wrote a design sheet of a specific applet and implemented it as a final project work. The geometrical object of the applet and its construction were provided, but the ISTs had autonomously to design and implement the educational structure. The geometrical objects on which the ISTs could choose to focus on are: a parallelogram that can be continuously transformed into a rectangle; a triangle with highlighted heights, axes, bisectors, and medians; a prism that continuously changes in its plane development; a solid composed by a cube surmounted by a cylinder. Finally, each IST individually carried out a metacognitive analysis of the resource created by their group, guided by some stimulus questions.

In the first laboratory meetings, the activity of the ISTs has been strongly scaffolded, while in the subsequent meetings, the scaffolding gradually faded [9, 10], mainly for what concerns the educational part of the applet (guiding questions, feedback, remarks, theoretical notions, …), so that the ISTs were involved both in decision-making processes and in metacognitive reflections on the use of the GeoGebra potentialities for teaching and learning the topic at stake.

In this study, within the research framework concerning the different levels of awareness needed to be a "real teacher" [8] and the necessary shifts of attention to be promoted in order to foster students' learning, we address the following explicit research questions: (1) Does the designed educational path improve the participants' awareness-in-counsel? (2) What is the ISTs' perception of the educational path for their professional development?

We used a case study methodology [11] and different kinds of data have been collected: the design sheet written collectively by the groups of ISTs; the GeoGebra applet created by the groups of ISTs as a final project work; the sheet containing the individual metacognitive analysis of the created GeoGebra applet and its educational potentialities; the individual answers of the ISTs to a final questionnaire.

The three researchers separately carried out the analysis of the productions of each group. They compared the design and the metacognitive reflection with the produced applet. The analysis of the outcome was based on the didactical suggestions and scaffolding provided by the ISTs to foster the use of the applet and students' learning. The authors identified and coded the excerpts of the ISTs' individual answers to the questionnaire concerning the perceived impact of the educational path. Finally, the main emerging themes have been discussed to reach an agreement and answer to the research questions.

4 Results

In this section, we answer the first research question about the increase of the awareness-in-counsel of the ISTs involved in the educational path. To this aim, we analyse the GeoGebra applet produced by two groups of ISTs, comparing it with the corresponding (*a-priori*) design sheet and the (*a-posteriori*) metacognitive reflection. In tune with [3], for each group, we will follow the evolution of the ISTs' awareness, focusing on *what* they designed, *i.e.* the object of the design and the students' difficulties that it should allow to overcome; *why* the resource has been designed, *i.e.* the cognitive processes on which the design should have an impact; *what tools* were used to reach the didactical aim; and, finally, *under what conditions* the resource should be used to foster students' learning, *i.e.* what should be the use of the resource within the learning path of the students.

We chose to focus on Group 1 and Group 2 since they chose two different mathematical objects to work on and their evolution is representative of that displayed by the other groups of ISTs.

Group 1 chose to work on the planar representation of a prism, while Group 2 chose to work on the continuous transformation of a parallelogram into a rectangle.

In Table 1 we synthesized the *a-priori* design and the *a-posteriori* metacognitive analysis carried on by Group 1 about their applet.

Table 1. Group 1's *a-priori* design and metacognitive analysis in terms of *what* is the object of the digital task, *why* it is designed, *what tools* have been used, and *under what conditions* the resource should be used.

Group 1	DESIGN	METACOGNITIVE ANALYSIS
WHAT?	a file allowing the visualization of surfaces	a sequence of tasks that can be faced one by one thanks to a slider and allows one to visualize a polyhedron as a set of polygons on different planes
WHY?	to foster visualization, exploration, self-assessment	to foster, behind the visualization, the exploration, the construction of mathematical meanings, and self-assessment
WHAT TOOLS?	sliders to change the number of sides of the prism and their length input fields to count the number of vertices, sides, faces input fields to compute the total surface and the volume of the prism	sliders, allowing the exploration of the prism and the continuous transformation of the prism in its planar representation input fields, allowing to give immediate and facilitative feedback to make the students autonomously find the solution checkboxes to verify the correctness of an answer
UNDER WHAT CONDITIONS?	in the classroom, with students grouped in pairs, since it is an explorative file	individually, at home or in the classroom for the exploration, then collective discussion to favor the connection of pieces of knowledge

During the design phase, Group 1 generically declared they wanted to design a resource addressing the "*students' difficulty of visualization of solids and identification of their elements (vertices, sides, faces)*". Their first idea was quite vague for what concern *what to design*: they wanted to produce a file to foster "*visualization, exploration and self-assessment*", without further explanations. They had in mind to use, as *tools*, "*sliders to change the number of sides and their length, and input fields, to compute the total surface and the volume of the prism*". Moreover, for what concerns the *use of the resource*, the ISTs suggested that it should be exploited by pairs of students or individually, at home or in the classroom, since the applet should be mainly explorative.

After the design and implementation process, the awareness of the ISTs of the didactical potential of the resource seems to be increased. The joint analysis of the applet they created, and their metacognitive reflections allowed us to highlight a careful design, with specific and often conscious choices aimed at guiding the users to develop specific awareness-in-action and awareness-in-discipline. For example, the applet includes some remarks such as "*moving the sliders* […] *you can face the task with a different prism*" (Fig. 1). Commenting on this design choice, an IST of Group 1 declared that "*the remark*

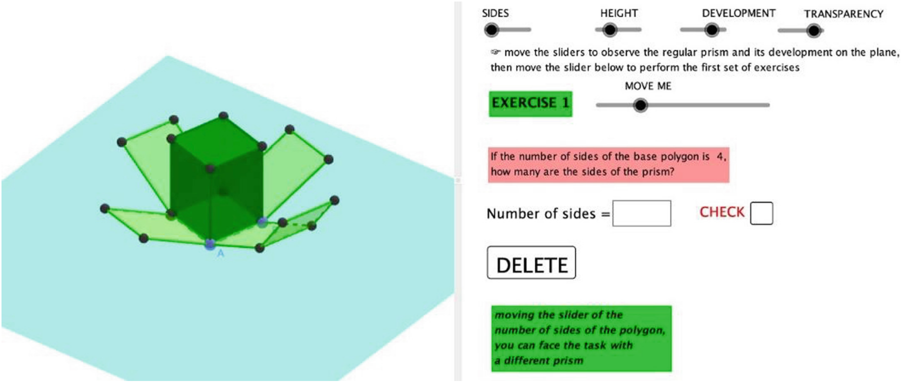

Fig. 1. A screenshot of the GeoGebra applet created by Group 1 concerning the planar representation of a prism.

suggests focusing on what is invariant when some data change", so explicitly promoting a shift of attention [8] in the students' minds. Another IST of Group 1 addressed cognitive, affective, and metacognitive levels of learning, saying that "*the students are invited to face the tasks by changing the initial parameters, in order to obtain general rules, so learning by their own mistakes. This should favor a greater engagement of the student and, at the same time, their reflection on their own learning process*". Moreover, the same IST discussed the structure of the resource as a sequence of tasks that progressively should bring the students to achieve the identified didactical goal, *i.e.* discover the formula for the surface of a prism:

> "*A slider has been introduced to give the students the possibility of having a sequence of tasks of increasing level of difficulties*; [...] *students start with the explorative phase, then they pass to the operative one. The first task concerns* [...]. *For each request, feedback is envisaged, and, in case of a wrong answer, some suggestions are provided to obtain the result. The second task consists of true/false questions, and it is preliminary to the third task, where, through some guiding questions, the students "discover" the formula for calculating the lateral and total surfaces of a prism*".

About the *why* issue, concerning the specific goal of the resource, the ISTs were more precise after the design and implementation process. One of them said that:

> *"the applet allows to explore a set of regular prisms so that the students grasp the mutual relations between the different elements. The applet envisages also self-assessment with some remarks guiding the student in searching for a general method to analyse such a solid".*

Another IST declared that "*the applet is aimed to enable the students to correlate in a stable way (i.e., by a formula), the number of sides, vertices and faces of a prism*". Moreover, in the metacognitive *a-posteriori* analysis of the produced applet, the ISTs have been able to associate each digital tool to a specific didactical goal. One of them declared that "*the use of the functionalities offered by GeoGebra, such as the sliders and the planar representation is crucial to foster the development of the students' abstract thinking*". This addresses a fruitful feature of Mathematics as a discipline and displays the IST's awareness-in-counsel about the didactical potential of the applet to favour the students' shift of attention towards a crucial epistemological aspect. Another IST said that:

> *"the possibility to visualize the planar representation of the prism, together with the sliders and some guiding questions with immediate feedback of the correctness of the answers, should make the student reflect on possible mistakes and improve their capability to learn".*

It is worthwhile to notice that an IST declared that the applet determines "*a relationship between the image and who observe it [...]; the opportunity to modify the parameters allows to better understand the figure*", so highlighting the opportunities of an individualized teaching/learning of Mathematics through careful use of technology, and in particular digital tasks [12, 13].

Finally, also the idea about the *conditions* under which the resource should be used evolves and becomes more precise and aware: in the *a-posteriori* analysis, some ISTs of Group 1 suggested integrating the individual use of the resource with a collective discussion. For example, it arises in the following excerpt: *"after the use of the applet by each student or pairs of students, a collective discussion in the classroom will be crucial to make remarks and awareness arise by the students about the connection with previously acquired pieces of knowledge".*

Group 2 chose to work on the continuous transformation of a parallelogram into a rectangle through the translation of a triangle.

In Table 2 we synthesized the *a-priori* design and the *a-posteriori* metacognitive analysis carried on by Group 2 about their applet.

During the design phase, Group 2 declared they wanted to produce a file concerning the idea of equidecomposability of planar figures. The group did not identify a specific students' difficulty to be addressed, but they said that the goal of the resource was to foster "*visualization, remediation and exploration*" (*what to design*). About the *technological tools* to be used in the implementation of the applet, the ISTs provided a list containing "*buttons, sliders, input fields*", without explaining their educational function within the applet. They declared that also "*drag and drop functionality and the automatic computation of areas*" should be used, in order "*to support the students' understanding*". Moreover, for what concerns the *use of the resource*, the ISTs suggested that it should be exploited in the classroom, with students working individually or in groups.

Table 2. Group 2's *a-priori* design and metacognitive analysis in terms of *what* is the object of the digital task, *why* it is designed, *what tools* have been used, and *under what conditions* the resource should be used.

Group 1	DESIGN	METACOGNITIVE ANALYSIS
WHAT?	a file supporting the idea of equidecomposability	a file to make the students understand where the formula for the area of the parallelogram comes from
WHY?	to foster visualization, exploration, remediation	to foster the awareness of the relation between the measure of the sides and the areas to deepen the relationship between the equivalence and the congruence of polygons to discover the formula of the area of a parallelogram to enable the students to understand that the mathematical formulas come from reasoning to connect pieces of knowledge
WHAT TOOLS?	buttons, input fields, sliders drag and drop automatic computation of areas to support the students' understanding	sliders, to visualize the translation automatic computation, to verify the equivalence of figures check boxes to enable students to visualize the process in different steps
UNDER WHAT CONDITIONS?	in the classroom, individually or in groups	integration between manual artifacts and virtual artifacts

The applet produced by Group 2 is characterized by a design that strongly scaffolds the students' exploration of the continuous transformation of the parallelogram into the rectangle. The ISTs inserted some instructions guiding the students in using some tools, such as the drag and drop function when moving the cursor, or the button allowing to see the measure of areas or length of sides (blue writings in Fig. 2). These instructions are supported by remarks aimed at supporting the students' noticing and monitoring of what the applet allows them to observe. For example, "you translated the triangle AED along the side EB and you obtained the rectangle EGCD" or "you will notice that AB = EG and DE = CG" (black writings in Fig. 2). Commenting on this aspect in his metacognitive analysis of the applet, an IST of Group 2 said that.

"*the resource aims to bring the student to aware and meaningful learning through an experimental approach guided by some suggestions. The interaction with the software GeoGebra, the visualization and virtual manipulation of figures, the use of specific tools for computing lengths and areas induce the student to deepen the meanings and discover new pieces of knowledge*".

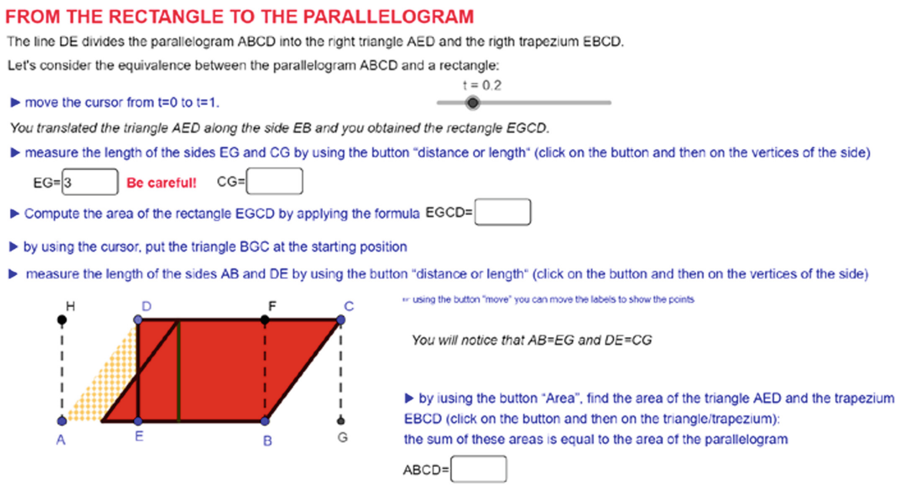

Fig. 2. A screenshot of the GeoGebra applet created by Group 2 concerning the equivalence between a parallelogram and a rectangle. (Color figure online)

Focusing on the experimental approach, another IST declared that "*the applet allows the concretization of the knowledge*".

In the *a-posteriori* analysis of the resource, the ISTs of Group 2 motivated the object of the design (*what to design*) saying that "*the concept of the surface of a planar figure is a critical aspect for many students*". The constructed resource is described as "*a file supporting the students' understanding of the fact that formulae come from reasoning*". In this sense, the digital resource conveys not only the learning of mathematical contents but also the cultural and epistemological value of the discipline, hence promoting the development of students' awareness-in-discipline. About the *why* question, the ISTs identified different goals of the applet in their *a-posteriori* analysis: it should foster the students' awareness of the relation between the measure of the sides and the areas; it should allow deepening that congruent figures are equivalent, while equivalent figures could be not congruent; it should favor the connection between pieces of knowledge and allows self-assessment.

Moreover, in the *a-posteriori* metacognitive reflection on the produced resource, the ISTs have been able to associate each technological tool they used with a specific educational aim. This constitutes a significant improvement with respect to the degree of awareness displayed in the design phase. For example, an IST declared that "*the sliders allow to highlight the crucial steps, providing the student with a clear logical sequence*".

Another IST commented about the links between the technological tools and her own individual ability to use them in a significant way. She declared that.

> "*the choice of some functionalities depends on my ability in using the software. At my level of expertise, I have been able to use sliders, check boxes, and input fields which allowed me to give meaning to the activity, which turned out to be richer with respect to an activity in a traditional environment*".

Finally, the ISTs of Group 2 chose to mainly focus on the *conditions* under which the resource they created could be used, also connecting them to the individual preferences of learning: "*Since each student has a preferred learning channel, the integration of methods and tools (cardboards, videos, software,…) is useful to impact different kinds of intelligence*". Another IST of Group 2 suggested different ways to use the resource:

> "*It is possible to give the resource to the students, allowing them to interact with it: in this case, they will answer the questions and fill in the blanks (individually or in pairs). Then, a subsequent collective discussion in the classroom will be suitable to compare the different answers provided by the students. Differently, the construction of the file could be proposed to the students (providing them with the protocol of construction) as an in-depth activity devoted to the most interested students. They could be the tutor of their classmates in difficulty*".

In tune with this idea, also another IST suggested proposing the activity into two different phases, envisaging the devolution of the construction of the resource to the students, so engaging them more deeply:

> "*during the first phase the students in small groups construct their parallelogram, following a protocol of construction; during the second phase, a collective reflection guided by the teacher is carried out in the classroom, so that the students could grasp that the parallelogram has the same area but a different perimeter of the rectangle with the same basis and height*".

For what concerns the second research question, regarding the ISTs' perceived impact of the educational path on their professional development, we analyse the ISTs' answers to the final questionnaire submitted to them after the conclusion of the educational path. In this survey, the questions concern (a) the previous experience with the software GeoGebra, (b) the criteria that guided the design of the GeoGebra applet, (c) the difficulties encountered during the design and implementation of the final project work, (d) the kinds of the possible increased knowledge (pedagogical, mathematical, technological) after the educational path.

For what regards issue (a), about 86% of the participants did not use GeoGebra before or had only a basic experience with it, mainly using files created by others (Fig. 3). Moreover, about 72% of the participants gave a score less than 5 in a scale from 0 to 10 to their own knowledge of the software. This data suggested that the participants' technological background, in particular concerning the software GeoGebra, was not sturdy:

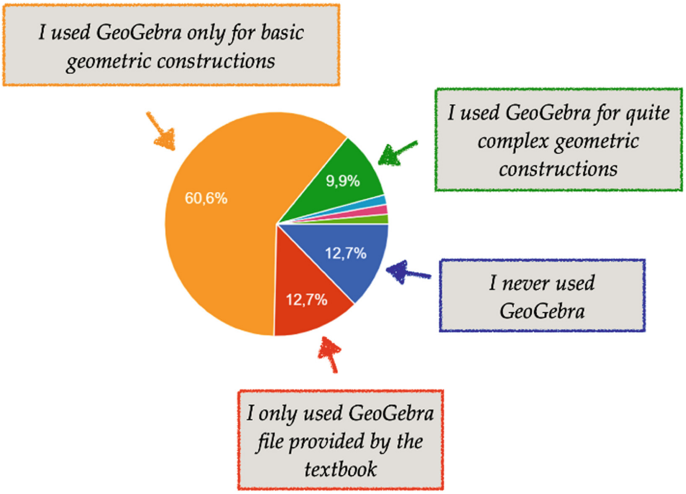

Fig. 3. The statistics of the ISTs' answers about their previous experience with GeoGebra.

The qualitative analysis of the ISTs' answers, mainly of those of kind (d), allowed us to highlight their perception of the impact of the educational path on their professional development. Many ISTs appreciated the intertwinement between technology and pedagogy: an IST declared "*I increased my technological competencies and mainly my awareness in using GeoGebra, grasping some educational potentialities of the software*"; another participant said: "*I really understood that acquiring digital competencies granted the improvement of the teaching and the acquisition of knowledge by the students*". Some ISTs focused on the opportunity of improving the students' learning by exploiting the digital resources they created not only at the cognitive level but also at the metacognitive and affective ones. This arises in the following answer: "*Now I can teach interactive and dynamic lectures which will engage the students and support them in strengthening the previous knowledge, acquiring new contents, reflecting on them and self-assessing their own learning*". Linked with this theme, also the inclusion issue is mentioned in some answers, such as the following one: "*Working with GeoGebra supports geometric constructions and consequently could favor the inclusion of students with specific learning difficulties and poor motivation*".

Another recurrent issue is the perception of the increasing of awareness, which was an explicit aim of our project. This arises in many answers such as "*My knowledge and awareness increased. In the last days, I used the applet concerning the important points of a triangle I created. The students understood this topic, thanks to the use of the software, and faced it with more pleasure*". Another IST declared "*I learned to use GeoGebra with more teacher's awareness. I discovered many functionalities that I did not imagine. They are essential to favor the teacher's work and their didactical choices*", referring just to the "teacher's awareness" which is the awareness-in-counsel, according to [8]. Another IST declared that:

"*Until now I considered GeoGebra only as a tool to enable students to visualize some facts. I never thought that was possible to create authentic didactical files, with guiding questions and automatic feedback, through which the students could autonomously interact in an explorative approach to a specific topic*".

It is worthwhile to notice that another theme emerging from many ISTs' answers concerns their perception of joint work in the group. Generally, this approach has been appreciated as an opportunity to share difficulties and doubts, like in the following answers:

"*Working in a group has been very useful since we shared ideas and doubts. I feel this supports my professional development"; "the collaboration within my group has been very positive; we discussed a lot of the students' typical mistakes and found collective solutions to the design and implementation troubles. It would be great if in all the job contexts there was the same approach*".

5 Discussion and Conclusion

In this paper we presented the outcomes of a case study carried out with 114 ISTs from different lower secondary schools of region Marche, in Italy. They were exposed to an educational path where they have been involved in the design and implementation of digital resources for their students, by using the software GeoGebra. We investigated 1) to what extent the awareness-in-counsel of the ISTs increased and 2) the ISTs' perceived impact of the educational path, and, in particular, of the engagement in the process of designing digital resources, on their professional development.

For what concerns the first research goal, our analysis highlighted that, standing some differences in the design, generally the ISTs displayed a change of perspective with respect to the educational potentialities of careful use of the software GeoGebra. They grasped the strong intertwinement between the mathematical content, the pedagogical aspects, allowing to consider the critical element of that content for the students' learning, and the technological resources, which can support the overcoming of the students' hardships. As a consequence, many ISTs who previously had a poor and limited experience with GeoGebra, declared their intention to autonomously produce GeoGebra applet for their teaching in future, in order to have an impact on the specific difficulties and learning needs of their students. Within the process of designing digital resources, the teachers generally identified didactical steps aimed at guiding the students in the learning process, so displaying an increased awareness-in-counsel as the sensitivity to what others need to develop their own awareness-in-action and awareness-in-discipline. In some cases, the resource has been used to convey some epistemological values of Mathematics, such as the idea of generalization or the cultural genesis of mathematical formulas.

As far as the second research goal is concerned, some recurrent issues emerged from the ISTs' answers to the final questionnaire they filled in after the conclusion of the educational path. Generally, the ISTs perceived a positive impact of the experience on their professional development, mainly reporting a new awareness about the large educational potentialities of the software GeoGebra, allowing them to improve their students' learning also at the metacognitive and affective levels. Moreover, the ISTs appreciated the collaborative design and implementation process that they carried out working in small groups, identifying it as a model for collaboration with their colleagues.

As a further development of the research, we planned to propose a second edition of the educational path, re-designed on the basis of the strengths and weaknesses of the first edition, according to the design-based research model. From the research point of view, we would like to deepen the investigation of the cooperative learning carried out by the ISTs during the laboratory sessions with a specific focus on the group dynamics and the possible misalignment between the participants in the design or implementation processes. In particular, we would like to carry out a joint analysis of the ISTs' screens during the work sessions and *a-posteriori* individual interviews.

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A Digital Educational Path with an Interdisciplinary Perspective for Pre-service Mathematics Primary Teachers' Professional Development

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Abstract. In this study we present an experimental research which analyses a designed pedagogical device based on the Core Concept (CC) to promote the pre-service primary teachers' (PTs') evolution of cognitive processes and reconstruction of mathematical meanings. The PTs have been involved in an educational path in which they solved an arithmetic-algebraic task, working in small groups in a learning digital environment. The task has been used to provoke a cognitive conflict and social interactions to foster the discussion and make different perspectives emerge. We analyzed the PTs' solutions through Radford's model concerning the levels of generalization. Our analysis, supported by the PTs' reflections, allowed us to highlight the crucial role of the CC, within the pedagogical device, in favoring the PTs' transition from the factual level of generalization, to the contextual one, to the symbolic one. Moreover, previously unforeseen aspects arose: a mutual interplay between the mathematical goal and the understanding of the CC by the PTs arose.

Keywords: Professional development · Core concept · Pre-service mathematics teachers · Relations and functions · Remote learning

1 Introduction

Recently interdisciplinarity and teachers' professional development have been indicated as two of the major challenges for Mathematics Education (Bakker et al. 2021).

Working on multiple dimensions is nowadays necessary to tackle complex problems, but the logic of the disciplines alone, does not guarantee a possible dialogue. Hence the need to grasp the complexity of the processes and distinguish different phases in them.

Moreover, the need of deepening affordances and limitations of remote teacher education has been highlighted and more experimental studies on this approach should be carried out (Perry et al. 2021). In this paper we present an experimental study carried

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out within an interdisciplinary perspective (Choi 2017) and fully conducted in remote learning by three researchers in Mathematics Education and a researcher in Teacher Education. The research involved pre-service primary teachers (PTs) from two different Italian universities who were asked to collaboratively work online to solve an arithmetic-algebraic task with the aim to foster the construction of mathematical meanings through the Core Concept (CC).

In designing the educational path for PTs, we thought that a significant role could be played by the Core Concept (CC), an essential construct of Teacher Education, having metaphorical meaning and allowing easier access to disciplinary ideas. The CCs are essential concepts recurring along a disciplinary curriculum and having an organizing value for the construction of knowledge; they mirror the structure of the discipline, encompassing both epistemological and pedagogical aspects. Some examples of CCs in Mathematics could be "spaces and figures", "measurement", "number", "proof", "relations and functions" (Robutti 2000).

In our educational path we used the CCs as key elements fostering the PTs' transition from the student-perspective to the teacher-perspective awareness about their mathematical knowledge as students, should be elements allowing the development of PTs' professional awareness.

The study pursues two intertwined goals: from an educational point of view, it aims at fostering PTs' professional development through a pedagogical device (Berten 1999) involving a careful use of communication technology fostering the peer-discussion; from the research point of view, we are interested in investigating to what extent the use of a pedagogical concept like the CC could support the achievement of a key mathematical goal, such as the generalization of the concept of relation (Montone et al. 2021).

To reach these goals, we analyzed the PTs' solutions of arithmetic-algebraic tasks, using Radford's level of generalization (Radford 2001, 2010) as a theoretical lens.

Finally, the role of technology is fundamental, as the activities are designed to be held online. It plays an important role in ensuring the random distribution of the tasks to be solved and discussed, the monitoring and sharing of the interactions among PTs from teachers. Furthermore, the digital nature of the learning environment requires a reflection on the role it assumes in shaping the activities about the CC and the evolution of Radford's level of generalization.

2 Theoretical Framework

Following Radford (2001), we assume a socio-cultural semiotic perspective to identify three levels of generalization when students face an arithmetic-algebraic task: the factual level, in which students solve the task operatively, performing iterated actions on the concrete objects the task is focused on; the contextual level, in which students perceive the emergence of a general structure from the actions performed and recognize it as a mathematical object; the symbolic level, in which students elaborate the mathematical meanings in general terms. The three levels of generalizations manifest through some semiotic means. From the linguistic point of view, the factual level is characterized by the use of personal and deictic pronouns, adverbs of time like "always", verbs indicating perception or actions, possibly iterated, mainly in the first (singular or plural) person. The contextual level is characterized by a hybrid language, where both abstract and situated elements coexist. The symbolic level is characterized by an impersonal and not ostensive language, which refers to a general mathematical object, possibly by means of specific mathematical formalism. In tune with Radford's model (2001, 2010), we recognize an evolution of the cognitive processes, from the simulation of concrete actions and counting (factual level), to the recognition of structural regularities and their translation in numbers (contextual level), up to not context-bound, general algebraic relations (symbolic level). According to Radford, to favor the transition of students towards higher levels of generalization, two elements are crucial: a good mathematical problem and social interactions.

In this respect, we used a task to provoke a cognitive conflict (Piaget 1975; Laurillard 2012) and social interactions (Vygotsky 1962) to foster the discussion and make different perspectives emerge. But our context, characterized by PTs, required something more (Di Giulio and Defila 2017). Indeed, they need to reconstruct mathematical meanings and progressively assume the teacher's perspective on them. Taking in mind this double aim, we designed a suitable pedagogical device involving a significant open task, the peer discussion and the CC as underlying theoretical element. The CCs, as elements that reflect the structure of the discipline, encompass both historical-epistemological and pedagogical aspects (Olmi 2000; Crosswhite and Anderson 2020). On the one hand, the CCs are key tools for the teachers, supporting the design and action for learning (Berthoz 2012); on the other hand, they favor the students in progressively grasping the epistemology of the discipline. The CCs are characterized by three essential features: verticality, since the CCs cyclically recur along the disciplinary curriculum; horizontality, since they favor the link with other contents of the same subject and with other subjects; generativity, since their metaphorical power supports the teachers' and students' orientation in the discipline and in the exploration of new topics, offering an interpretative model (Rossi and Pentucci 2021).

3 The Research Methodology and the Educational Path

The designed pedagogical device for the educational path is characterized by the two arithmetic-algebraic tasks inspired by Radford (2001, 2010), which the PTs should face:

Task 1

A sequence of symbols begins as follows:

Which symbol do you find in the 17th position? Where is the 5th star?

Generalization question: "Which symbol do you find in the 1987th position?".

Task 2

Silvia uses 3 cans to build a pyramid of 2 floors, as shown by the figure. She uses 6 cans to build a pyramid of 3 floors. How many cans does she use to build a pyramid of 5 floors, with the cans arranged in the same way?

Generalization Question: How many cans does Silvia use to build a pyramid of 100 floors, with the cans arranged in the same way?

The generalization questions aimed to make a cognitive conflict emerge, revealing the inadequacy of the factual approach (involving the drawing and the counting of the concrete objects). The tasks allow different strategies and through the generalization question should force the PTs to link their informal knowledge with the formal one.

Other elements of the pedagogical device are the peer discussion, and the CC.

All the elements of the pedagogical device had a specific function in promoting the PTs' professional development: the task and, in particular, the generalization question aimed to make a cognitive conflict emerge, revealing the inadequacy of the factual approach; the peer discussion aimed at fostering the collective evolution of the different solutions and perspectives; the introduction of the CC aimed to provide students with a trigger to overcome the cognitive conflict (Rossi and Pentucci 2021).

The pedagogical device has been used in an educational path that involved 330 PTs at two different universities, one located in the center of Italy (University of Macerata) and one in the south of Italy (University of Bari). All PTs were attending a five-year course. The students at the University of Macerata attended the course of Teacher Education in their third year, whilst the ones at the University of Bari attended the course of Mathematics Education, in their fourth year. The teachers of these courses are the authors of this paper. The path lasted about one month and was performed using distance learning, due to the Covid-19 pandemic. The participants were divided into groups of four PTs from the same university. All the interactions among students and with teachers happened through digital communication channels, such as Microsoft Teams, Google Meet, Youtube, WhatsApp. The educational path envisaged the following steps:

- (S1) Groups were provided with an arithmetic-algebraic task. They were asked to answer an open-ended online written questionnaire requiring: S1.Q1) How do you solve the task? Explain your reasoning. This step lasted one week.
- (S2) All the PTs were exposed to two 1-h lectures about the CCs and the CCs in Mathematics, during which the general features of the CC (from the Teacher Education perspective and the Mathematics Education perspective) were discussed, and examples of CCs were provided, without any reference to the task the PTs had to solve.
- (S3) The groups, communicating at distance, reworked their first solution, within four days, based on the generalization question. They were asked to answer a written questionnaire including the following questions: S3.Q1) Does your solving process change? In which way? S3.Q2) What connections with other mathematical topics would you highlight if you should present the task in a classroom?
- (S4) Each group discussed at distance the elaborated answers with a group of the other university. This step lasted one week.
- (S5) Each group had five days to answer a written questionnaire to possibly improve the solution and metacognitively reflect on the whole experience. Among other questions,

we asked: S5.Q1) Do you want to modify your previous solution of the task? S5.Q2) How could the CCs influence your design and activities as a teacher?
- (S6) The teachers gave an online lecture to all the PTs, aimed at analyzing their productions and providing joint feedback about them.

According to a design-based approach (Swan 2020), the design of the pedagogical device, its use and the validation of the path were strongly intertwined and evolved during the activities. Also, the self-study methodology (Tidwell et al. 2009) was applied since the researchers were also the practitioners and handled the educational path. To validate the path, a qualitative analysis based on the Radford's model of the three questionnaires (both cognitive and metacognitive) answered by PTs was carried out, according to the criteria of credibility, dependability, transferability, and confirmability (Guba 1981), to ensure trustworthiness. The researchers repeatedly read the PTs's answers and coded them individually, referring to the research goals and the theoretical framework; then they discussed the emerging themes until they agreed on the most relevant ones (Sharma 2013).

3.1 Research Questions

- Can peer interaction supported by a task in which there is a question of generalization lead students in training to reconstruct mathematical concepts?
- How do university students behave when faced with a task with a generalization question? Do they go through the three Radford's levels of generalization?
- Does the CC allow PTs to become aware of the "formal" mathematics underlying an arithmetic-algebraic task?

4 The Project and the Structure of the Educational Path

The project involved 330 PTs from the Italian universities of Macerata and Bari. The PTs of the university of Macerata attended the course of Teacher Education in their third year of study, while the PTs of the university of Bari attended the course of Mathematics Education, in their fourth year. In this project technology plays a major role, as it allows to support the processes involved in the educational path in its three main functions (Albano et al. 2020): sending and viewing; processing and analysis of the data collected during the lessons; provide an interactive environment, where students can interact to work individually or in groups on a task or to explore mathematical/scientific content (Perry et al. 2021). The use of the digital resources in organizing the activities of the educational path allows to customize both the types of tasks and the interaction among the PTs (Montone et al. 2021).

Along the educational path, the PTs were parted in small groups of people of the same university and required to solve an arithmetic-algebraic task working online. Then, they were exposed to two one-hour lectures on the CC in general terms and on the CC in Mathematics and, after having worked together with a group of the other university, they have had the possibility to rework their first solution. In the next phase, the PTs were required to reflect metacognitively on the whole experience. Finally, the teachers of the courses taught an online lecture, in order to analyze the PTs' productions and give joint feedback. The PTs provided their solutions and metacognitive reflections through three online open-ended questionnaires.

Each component of the pedagogical device (Berten 1999) had a specific function within the educational path: 1) the arithmetic-algebraic task, designed according to the Radford's model on the level of generalizations (Radford 2001), should have brought out a cognitive conflict and induced the generalization of the concept of relation; 2) the peer discussion, completely carried out at distance through different communication channels, should have fostered the comparison of different viewpoints and supported either the improvement of communication skills and the evolution of the collective solutions and metacognitive reflections; 3) the CC as underlying theoretical element, should have favored an easier access to the mathematical content by the PTs, supporting the overcoming of the cognitive conflict, and fostered the PTs' transition from the student-perspective to the teacher-perspective.

5 Results

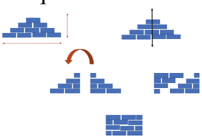
The analysis of the texts revealed that at step S1 about 32% of groups solved the task at a contextual level, while the remaining ones solved the task at the factual level. There were no solutions at the symbolic level. In step S2 all students overcame the factual level and about 35% of students reached the symbolic level. At the end of the learning path, 71% of students achieved the symbolic level. In the following tables, we will focus on the works of two groups within steps S1, S2 and S4 of the educational path.

These transcriptions show the PTs' transition through the three levels of generalization (Radford 2001), as expected. The first version of the task induced PTs to find a solution at the factual level, which turned out to be insufficient when the generalization question was added. Hence PTs referred to the CC, which supported them in finding a general and effective formula, thanks to its features of generativity, verticality and horizontality. The CCs acted both epistemologically and pedagogically: they conveyed the idea of generalization, and they are recognized as a fil rouge for the teaching path. In addition, in this answer students put together mathematical and pedagogical knowledge, in an interdisciplinary way, to revise their solution and complete it. PTs gradually modified their solving process: they shifted from a factual operativity, directly acting on the cans by counting, to the recognition of a contextual regular structure connecting numbers (the number of cans on the basis of the pyramid with the number of floors); finally, they identified an algebraic relation referred to mathematical objects and independent from the context. Moreover, in this evolution, we note that PTs switched from the arithmetic semiotic register to the algebraic one, through the geometric one. The different reformulations show how the mathematical meanings and the language evolve from the description of iterated actions, through the calculation of an area, to the general idea to calculate the sum of the first n natural numbers.

As in the previous example, the transition along the levels of generalization emerges, testifying the PTs' evolution of cognitive processes. All the above comments apply also to this case. Besides, here students got to use specific mathematical formalism, then came back to the contextual elements of the task. Moreover, even when they reached the

Table 1. First group's answers to the questionnaires

Task 1. Silvia uses 3 cans to build a pyramid of 2 floors, as shown by the figure. She uses 6 cans to build a pyramid of 3 floors. How many cans does she use to build a pyramid of 5 floors, with the cans arranged in the same way? 
Generalization question (provided within S2): How many cans does Silvia use to build a pyramid of 100 floors, with the cans arranged in the same way?

First group's answers	Authors' analysis
(S1) We solved the task by drawing a pyramid. Starting from the top, we went down, by adding one can for each floor: at floor 1 I have 1 can, at floor 2, I have 2 cans, at floor 3, I have 3 cans, at floor 4, I have 4 cans, and finally at floor 5, I have 5 cans, which bring us to 15 cans in all	PTs solved the task operatively, by performing concrete actions and counting (*drawing, we went down, adding, at floor 1 I have 1 can…).* We recognize a *factual level of generalization* by the use of verbs, in the first singular or plural person (*we solved, I have*), indicating iterated actions (*I have,…, I have*) on the concrete objects (*cans*) and linked to numeric operations
(S2) Our process changed, becoming more generative and effective. Our first solution works well for small numbers, but not for big numbers. We inevitably needed to change our approach. We chose to refer to the geometry […], we drew a pyramid with 4 floors, we halved it, obtaining two equal ''staircases", one on the left and one on the right. We rotated the right figure on the other one, thus obtaining a rectangle with basis (n + 1)/2 cans and height n cans. So, the product n(n + 1)/2 is equal to the area of the constructed rectangle 	PTs reworked their first solution, induced by the generalization question which revealed the inadequacy of the first approach, as they declared. The search for a solution seems to be oriented by the CC "space and figures". In this excerpt the *horizontality* of the CC emerges, since PTs passed from the arithmetic field to the geometric one. The *generativity* of the CC also arises, since PTs refer to a metaphorical rectangle formed by cans. We recognize a *contextual level of generalization* by the use of a hybrid language, where both situated and abstract elements coexist. There are some spatial references (*right*, *left*), verbs indicating action (*draw*, *halve*), references to material objects (*cans*) and concrete not material objects (*pyramid, figure*, *rectangle*). The cans are not viewed as single objects, but they are ideally grouped into a unique *figure* (*pyramid*) on which it is possible to act mathematically (*halve*, *rotate*). This process induces a formula. An integration of different perspectives and semiotic registers arises, as the formula and the figure prove

(*continued*)

Table 1. (*continued*)

(S4) By decomposing the figure, a rectangle having a basis equal to (n + 1)/2 and height equal to n is created. The product n(n + 1)/2 is equal to the area of the rectangle, i.e. the sum of the first n natural numbers	A *symbolic level of generalization* arises in the expression referring to abstract objects (*figure, rectangle*) and in the formula. The verbs are impersonal, there are not pronouns nor spatial references
(S4/Q1) After the additional question about the pyramid of 100 floors, we referred to the CC of "relations and functions", since we would like to find a general formula for all the possible cases. We think that the CC can influence our design for learning since it fosters the synthesis of contents. By the CC we can form a net structuring of the curriculum; moreover, we can give a linear direction to our teaching path, by identifying a *fil rouge*	PTs declared that, facing the additional question aimed at the generalization, they grounded their solution on the CC. They passed from the CC "space and figures" to the CC "relations and functions", highlighting the *horizontality* of CCs. As emerged by their reflections and the reworked solution, they searched for a *general formula for all the cases*. Here the *generativity* of the CC emerges, since it conveys the rich mathematical idea of generalization, hence the epistemology of the discipline. Moreover, PTs showed awareness of the meaning of the CC and its potential influence on the design for learning. They also recognized the *verticality* of the CC, seen as a *fil rouge* for the teaching path

Table 2. Second group's answers to the questionnaires

Task 2. A sequence of symbols begins as follows:  Which symbol do you find in the 17th position? Where is the 5th star? **Generalization question** (provided within S2): Which symbol do you find in the 1987th position?	
Second group's answers	**Authors' Analysis**
(S1) In the 17th position we saw the second triangle; from the 15th position, we continued to draw the symbols, according to the same sequence. So, following the multiplication table of 3, in position 6 we found a triangle, in position 9 a star, in position 12 a triangle, in position 15 a star,…, and in position 27 the fifth star	PTs solved the task by drawing the sequence of symbols up to the 17th position. We recognize a *factual level of generalization* using verbs of action and perception, in the first plural person (*we saw, we continued to draw*). These verbs refer to concrete objects (*triangle, star*) and are linked to numeric operations (*following the multiplication table of 3*). The last sentence shows the rhythmic repetition of words, suggesting something general, that continues in space and time

(*continued*)

Table 2. (*continued*)

(S2) Our perspective changed when we needed a general rule to find the symbol corresponding to any given position (i.e., 1987). It was necessary to identify and analyse the relations between symbols and numbers. The symbols reoccur according to a cyclic order of 6. This reasoning is based on an arithmetic progression, i.e., the difference between each symbol and the previous one [of the same kind] is a constant number of symbols (5). Since we add 6 to each symbol, we can talk about multiples of 6 (6n)	The additional question revealed the PTs the inadequacy of their first approach. To overcome the impasse, they searched *relations* between the symbols and their positions, i.e., they referred to the CC "relations and functions". The CC turns out to be *generative*, allowing PTs to change their perspective and see the mathematical structure of the problem. The *contextual level of generalization* displayed using a hybrid language, referring to general objects (*symbols, cyclic order*, *arithmetic progression)* but also including references to space, time and operations, as in the expression *the difference between each symbol and the previous one is a constant number of symbols*
(S4) We looked for regularities in the sequence. We started from the star. It is in position 3, then in position 9 by adding 6, then in position 15 by adding 6… In terms of multiples of 6 (6n), the circle will occur in positions 6n + 1 and 6n + 2, the star in position 6n + 3, the triangle in positions 6n + 4, 6n + 5 and 6n + 6. Hence, given a sequence (where symbols reoccur according to cycles of n), in order to find the symbol in position m, you need to identify the nearest multiple of n lower than m, then you take it out of m and see what number (from 1 to n) you obtain	PTs reached a s*ymbolic level of generalization*, as proven by the last sentence. They referred to a general, not context-bound solution, using a not situated language and a specific mathematical formalism. However, to obtain the final general explanation, PTs merge all the levels of generalizations. Indeed, they retraced the whole process, from the iterated action typical of the factual level (*by adding 6*), through the contextual level (*the circle will occur in positions 6n + 1,…*), to the symbolic generalization, where any reference to concrete objects vanishes
(S4.Q1) We experienced the role of the CC as a generative and unifying element. In the elaboration of our solution, the CC suggested how to find a general solution, searching connections with other mathematical topics. The awareness about this aspect will allow us to support our future students in a meaningful construction of knowledge, by using appropriate strategies. The discussion with the peers unfolded two layers: the identification of the conceptual knots of mathematics, and the shift from the empirical solution to the theoretical one	PTs became aware of the *horizontality* of the CC, which induces the link with other mathematical contents. Moreover, the PTs seemed to grasp the *generativity* of the CC in a double sense: epistemologically, it offered them a perspective to find a general solution to the task and, pedagogically, it will be significant for their future teaching action. PTs recognized the effectiveness of the discussion with the peers, both in identifying *conceptual knots* of the subject, and in inducing them towards a general solution

symbolic level in the explanation of the process, they again referred to iterated actions on concrete objects, which is typical of the factual level. We recognize the permeability and the coexistence of the levels of generalizations as new elements. Indeed, students went back and forth through the levels when they solved the task. Finally, on the one hand, the CC turned out to be a key element for the evolution to higher levels of generalizations, allowing the overcoming of the cognitive conflict arisen with the generalization question; on the other hand, the PTs' understanding of the CC evolved thanks to its use in the provided authentic task. As expected, the peer discussion was also a key element of the pedagogical device in the educational path of the PTs, as highlighted in the last row of Table 2.

In conclusion, thanks to different subjects involved in an interdisciplinary key and thanks to the digital nature of the learning environment, an evolution of mathematical levels of generalization has been realized.

6 Conclusion

To investigate the research goals, we collected and analyzed the answers to the open-ended online questionnaires, where the PTs shared their solutions to the arithmetic-algebraic tasks, their reworked solutions and their metacognitive reflections.

The outcomes of the educational path seemed to confirm the effectiveness of the designed pedagogical device based on the CC to promote the PTs' professional development and reconstruction of mathematical meanings. In the first step, the PTs have been required to solve a mathematical task; as expected, they faced it, for the most part, as students. The introduction of the CC, together with the peer discussion, modified their posture, inducing them to review the task also from the perspective of future teachers. Finally, the CC, thanks to its pedagogical trait, also facilitates the access to the involved mathematical aspects, as testified by the transition of PTs' productions towards higher Radford's levels of generalization. The PTs passed from factual solutions, involving drawings and counting in specific cases, to contextual or symbolic solutions, identifying underlying mathematical objects and relations allowing to solve a class of similar problems. Moreover, PTs displayed to have understood the pedagogical scope of this transition. Referring to the CC, PTs seemed to progressively grasp either epistemological aspect of Mathematics, overshadowing the context of the task and focusing on its mathematical structure, and pedagogical aspects, identifying the advantages of the use of the CCs for teaching. Our analysis of the PTs' solutions and metacognitive reflections allowed us to highlight that, as expected, the authentic task and its generalization question made the PTs face a cognitive conflict, and the CC acted as a trigger for its overcoming. A dynamic dialogue arose between the mathematical goal and the understanding of the CC by PTs, which developed in a mutual interplay. The CC revealed its value as a structuring and structured element: it gave structure to the educational path, promoting, within the pedagogical device, the PTs' transition towards higher levels of generalization; conversely, it turned out to be structured by its instrumental use within the mathematical task, through which PTs became aware of the role of CC as an organizing principle for the curriculum and the design for learning, hence as an element of simplexity.

Further, the metacognitive reflections shared by the PTs allowed us to highlight the key role of the peer discussion, fully carried out at distance by different communication technology channels. This confirms the key role of technology in the designing of the educational path. The PTs also declared that the peer discussion fostered the comparison between different viewpoints (students from different universities, attending different courses), and their progressive assumption of the teacher-perspective.

As future work, we would like to deepen the status of CC and its role in the Education of Mathematics Teacher through further theoretical and experimental research.

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Incremental and Interpretable Learning Analytics Through Fuzzy Hoeffding Decision Trees

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Abstract. Artificial Intelligence-based methods have been thoroughly applied in various fields over the years and the educational scenario is not an exception. However, the usage of the so-called explainable Artificial Intelligence, even if desirable, is still limited, especially whenever we consider educational datasets. Moreover, the time dimension is not often regarded enough when analyzing such types of data. In this paper, we have applied the fuzzy version of the Hoeffding Decision Tree to an educational dataset, considering separately STEM and Social Sciences subjects, in order to take into consideration both the time evolution of the educational process and the possible interpretability of the final results. The considered models resulted to be successful in discriminating the passing or failing of exams at the end of consecutive semesters on the part of students. Moreover, Fuzzy Hoeffding Decision Tree occurred to be much more compact and interpretable compared to the traditional Hoeffding Decision Tree.

Keywords: Learning Analytics · Incremental Learning · Hoeffding Decision Trees · Fuzzy Logic · Explainable Artificial Intelligence

1 Introduction

In the last decades, Artificial Intelligence (AI) has deeply transformed the way we live the technology. Digitalization together with the spread of fast networks and low-cost sensors have made possible the design of intelligent and pervasive systems that can interact with users and to learn models directly from data coming from these interactions. Also, this big availability of interconnected services daily produces a huge amount of data from which hidden knowledge to improve different processes could be extracted. Particularly, in the educational domain, Learning Analytics are new methodologies which combine Information

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Technology with the educational field, in order to create new tools to improve students' learning and the environment in which it occurs [1]. There are several examples of AI used for education, such as social humanoid robots interacting with children [2], augmented reality to support a behavioral lesson, tracking user interactions with virtual objects [3], smart and interconnected objects to improve the learning experience [4,5], data analysis techniques to extract useful knowledge from educational data [6,7] and to visualize them [8], etc. Interested readers could refer to [9] for a more complete review.

However, while Artificial Intelligence is gaining attention, there are also many concerns related to its improper use. For this reason, several countries have proposed guidelines to regulate the use of AI when dealing with sensitive data, such as the educational ones[1]. Specifically, automatic analyses are required to be explainable and thus trustworthy [10]. Final users should be able to understand not only the results of automatic analysis, but also the automatic process that has led to them. This is the goal of Explainable Artificial Intelligence (XAI), a new sub-field of AI that focuses on explanations. Explanation models have been categorized into two main groups, namely *ante-hoc* and *post-hoc* [11]. The first category includes methods that are able to explain their behavior by design [12]. In contrast, black-box models, such as neural networks, are not able to explain their processing, thus further algorithms, belonging to the second category, are applied to make them more interpretable.

In this paper, we will focus on ante-hoc methods, and in particular, we will exploit the fuzzy logic capability to model uncertainty and vagueness to represent reality through natural language. Fuzzy logic has been proven to be useful to design effective tools for explanations [13]. Moreover, it has been widely used in the educational domain since the learning behavior is inherently uncertain. It has been used to solve several tasks, such as customizing the learning materials in e-Learning systems based on user profiles [14], predicting the students' performance [15–17] and their engagement [18], supporting their learning [19], explaining the results of automatic analyses [20].

While one important factor to look for when designing learning analytics tools is explainability, another equally relevant factor, that should be taken into account, is time. However, most of the learning analytics methods built in the relevant literature are static. This is counterintuitive, since the learning process is itself evolutionary and adaptive. Recently, Recurrent Neural Networks have been used to predict the students' behavior taking into account their history [21], however these are black-box models that cannot be explained. Some first attempts at using incremental stream data analysis methods for educational data can be found in [22,23].

In this work, we take advantage of the evolving nature of students' behaviors present in the Open University dataset, reporting click-stream interactions of students with Virtual Learning Environments (VLEs), exploiting two stream-based classifiers, namely Hoeffding Decision Tree (HDT) [24] and its fuzzy version (FHDT) [25], to predict the students' outcomes in consecutive semesters.

[1] European General Data Protection Regulation - GDPR: https://gdpr-info.eu/.

Both algorithms build interpretable models, given that they create incremental decision trees, whose structure adapts to the incoming data and can be easily translated into incremental sets of *IF-THEN* rules. Moreover, FHDT is endowed with greater interpretability, because of the linguistic terms associated with the fuzzy partitions themselves, and it is usually less complex and more suitable to face the possible change in the distribution of features and labels over time, the so-called concept drift. Recently, HDTs have been successfully experimented for dealing with the streaming data generated in automotive [26] and next generation networks applications [27].

This paper extends the work in [28], wherein Fuzzy Hoeffding Decision Trees (FHDT) were proposed as a tool for Learning Analytics. Particularly, the time feature was exploited, and to this aim a subset of the Open University data was used to incrementally predict the students' outcomes for each semester. Indeed data belonging to the students' interactions with the Virtual Learning Environment are collected together with demographic information and information related to the courses and the students' assessments. The algorithms proved to be effective in adapting the models to the new data. Moreover, easy-to-understand explanations were returned. In this work, data belonging to different topics have been separately analyzed. In particular, the results achieved considering two different datasets, one containing STEM subjects and the other containing Social Sciences subjects, have been analyzed to verify if differences could be observed in the derived predictive models and in the final performance as well. Indeed, the main idea is that different learning and updating processes may be required for generating tree models from these two groups of subjects. Finally, we have further investigated the semantics of the obtained results through visual graphs of the fuzzy decision trees and properly showing some examples of *IF-THEN* rules.

The rest of the paper is structured as follows. The dataset adopted in the experimental analysis is described in Sect. 2. Section 3 describes the adaptive and interpretable techniques that have been used to predict the students' outcomes and to explain the process leading to the obtained results. Quantitative and qualitative evaluations of the results are discussed in Sect. 4. Finally, conclusions and future developments of our research are summarized in Sect. 5.

2 Data

A subset of the Open University Learning Analytics Dataset (OULAD)[2], previously published in [29], has been used for the analysis of this work. The dataset contains students' demographic information (such as gender, age, highest education level, etc.), students' assessments for a given course (e.g., numbers of previous attempts to pass a certain exam, average score in the intermediate assessments, number of finalized intermediate assessments, etc.) and details about the students' interactions with the VLE itself, as shown in Fig. 1. In particular, differently from other works present in the relevant literature, where aggregated

[2] Dataset: https://zenodo.org/record/4264397#.X60DEkJKj8E.

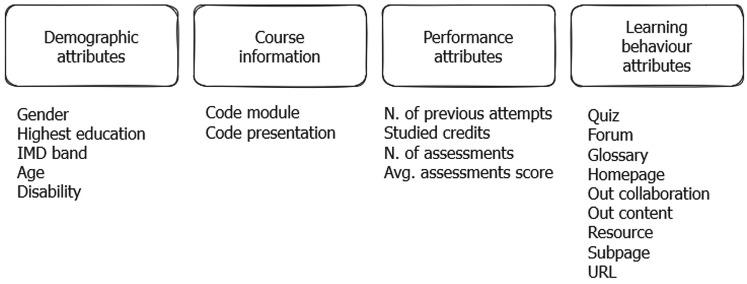
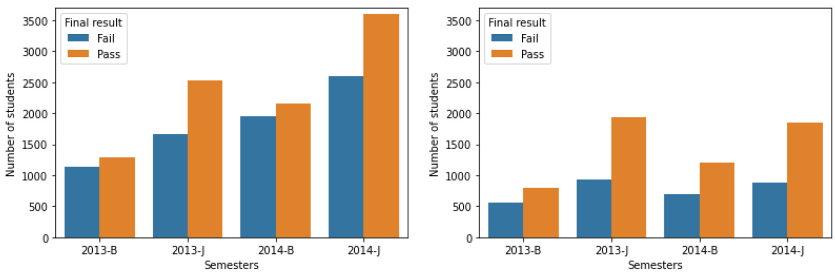


Fig. 1. Semantics groups of features in the considered dataset.

data regarding the interactions are used (e.g., the total amount of clicks), these data contain total clicks referring to each of the nine different support tools that are embedded in the VLE. Indeed, for the aim of our analysis, it is important to identify the tools that are mostly used when studying a given topic, and which ones could mostly help in passing the exam. Table 1 details the description of the features used in the current analysis. Each instance of data describes the behavior of a student attending a specific course during a semester of a specific year. Particularly, data belong to four sequential semesters of 2013 and 2014: in the dataset, the letter *B* is used for the first semester and *J* for the second one. Moreover, the courses in the dataset regard seven different topics belonging to two macro-categories: *STEM* and *Social Sciences*[3]. Each student is described through 20 features and the target feature related to the students' final assessments assumes the values *Fail* and *Pass*.



(a) STEM (b) Social Sciences

Fig. 2. Statistics of the considered data for the two considered groups of subjects: STEM and Social Sciences.

[3] Please note that courses with code module "AAA","BBB", and "GGG" belong to the category Social Sciences, whilst "CCC","DDD","EEE","FFF" are STEM.

Table 1. Description of the features used in the current analysis.

Feature	Description
Gender	Male or female
Highest Education	The highest level of education of the student at the time of enrollment
IMD band	Index of Multiple Deprivation band value of the place where the student lived at the time of enrollment
Age	The age of the considered student
Disability	Yes or No
Code module	Code of the specific course ("AAA", "BBB", "CCC", "DDD", "EEE", "FFF", and "GGG")
Code presentation	Code of the year and semester in which the exam took place (2013-B, 2013-J, 2014-B, 2014-J)
N. of previous attempts	Number of times the student attempted the final exam for a given course
Studied credits	Numbers of credits collected before the exam
N. of assessments	Number of intermediate assessments performed by a given student for a given class
Avg. assessments score	Average score of the assessments of a given student for a given class
Quiz	Number of tests a student answered for a given course
Forum	Number of posts on the course forum by a given student
Glossary	Number of times a given student accessed the glossary for a given course
Homepage	Number of times a given student accessed the homepage of a given course
Outcontent	Number of times a given student accessed the material external to the VLE for a given course
Subpage	Number of times a given student accessed the subpages of a given course
Url	Number of times a given student accessed URLs in the material of a given course
Out collaborate	Number of interactive activities among students
Resource	Number of times a given student accessed the resources of a given course

Since the aim of the analysis is to study the evolution of the learning behavior, we have considered a semester as a temporal unit (chunk), and we have partitioned the data in four sequential chunks corresponding to the four semesters under exam. Figure 2 shows data distribution of the classes *Fail* and *Pass*, for each semester, for both STEM and Social Sciences courses. Big differences can be observed from one semester to another one, and also between the two groups of subjects.

3 Models

In this section, we describe the tree-based models we have employed to study the educational dataset described in the previous section. Given that we have hypothesized a continuous stream of data over time, we have reverted to models capable to handle an incremental arrival of instances and a consequent incremental growth of the tree-based models themselves. In particular, we have adopted the Hoeffding Decision Tree (HDT) and its fuzzified version (FHDT), considering their structure to be updated incrementally as new chunks of labeled instances are available as an input of their own models. We recall that a decision tree is a classification model based on a directed acyclic graph, whose internal nodes execute a test on a certain attribute, the edges mirror the outcome of the test, and the leaves (terminal nodes) are characterized by instances with, in general, one or more class labels. The fuzzy version of a decision tree considers a fuzzy discretization of the input variables, by the definition of a linguistic fuzzy partition [25]. FHDT could be very helpful in tackling the current hot topic of explainable artificial intelligence models because it usually guarantees a balance between the level of classification performance (accuracy, precision, recall, etc.) and the degree of complexity of the model itself. Moreover, the usage of linguistic fuzzy partitions ensures a high level of semantic interpretability of the rules that can be extracted from the tree [30].

Training both considered algorithms, HDT and FHDT, includes two main phases:

1. the update of the statistics of the classes (binary outcomes of the students) in both the internal nodes and the leaves,
2. the expansion of the tree if certain conditions on some parameters are fulfilled.

FHDT differs from the classical HDT model in the following two aspects [25]:

- the update of the statistics at the various nodes composing the tree,
- the use of the fuzzy Information Gain and of the fuzzy Hoeffding bound to choose the best splitting attribute.

As regards the first difference, this is due to the fact that a training instance in the FHDT can reach more than one leaf because of the inherent nature of the fuzzy partition defined on each input feature. We have considered only triangular, strong, and uniform fuzzy partitions, thus exactly two output branches can be output at each split. Indeed, as discussed in [25], appropriate fuzzy metrics and statistics have been introduced and adopted during the incremental learning stage of a FHDT, namely the fuzzy membership degree, the local fuzzy cardinality of the whole node and the fuzzy cardinalities per class in a node.

As concerns the fuzzy Information Gain, in [25] the Hoeffding bound used in HDT has been properly modified adopting the fuzzy cardinality instead of the usual sum of the instances in a given leaf. More details on FHDTs can be found in [25].

The FHDT model can be further easily explained through linguistic IF-THEN rules, leading to the two target classes we have considered (PASS and FAIL). The rules can be easily extracted from the tree model by following the paths from the root to the various leaves. An example of the k^{th} rule (R_k) can be defined, in a formal way, as follows:

$$\begin{aligned} R_k : \textbf{IF} \quad & X_1 \ is \ A_{1,j_{k,1}} \quad \textbf{AND} \quad \ldots \quad \textbf{AND} \quad X_{F_k} \ is \ A_{F_k,j_{k,F}} \\ & \textbf{THEN} \quad Y = Pass \ with \ w_{pass}, Fail \ with \ w_{fail} \end{aligned} \tag{1}$$

wherein $j_{k,f} \in [1, T_f]$ is the index of the fuzzy set of partition P_f of input variable X_f. Moreover, w_{pass} and w_{fail} are the fuzzy cardinalities per class of the instances in each leaf node.

4 Results and Discussion

4.1 Experimental Setup

Two sets of experiments have been conducted with the twofold aim of identifying the most suitable incremental and interpretable algorithm to predict the students' assessments, and to verify if differences could be observed between the results obtained on data belonging to STEM subjects and those belonging to Social Sciences. Indeed, the hypothesis to verify is that different kinds of interactions are required by disciplines belonging to those different groups of subjects. Moreover, we want to observe whether differences in demographic information related to the students can be identified.

In the experiments, we have simulated the Test-the-train scenario: once a new $chunk_i$ is collected (with i= 2013-J, 2014-B, 2014-J), we first assess the performance of the current model on $chunk_i$ and then exploit it to update the model. The first evaluation step consists in using the chunk of the first semester of 2013 ($chunk_{2013-B}$) for training and the chunk of the second semester of 2013 for testing. Moreover, for the inference strategy, we have considered both the majority voting (MV) [25] and the Adaptive Naive Bayes (ANB) voting techniques [31]. In the experiments, we incrementally built decision trees using both classical HDT and FHDT. For FHDT models we considered both 3 fuzzy sets (FHDT-3) and 5 fuzzy sets (FHDT-5) for the partitions of the input variables. Finally, each input variable has been normalized in the range [0,1].

When analyzing the achieved results, we first carried out a quantitative evaluation of both STEM and Social Sciences. Quantitative measures have been extracted to evaluate the effectiveness of the compared algorithms in terms of predictive capability and model complexity. Then, we performed a semantic analysis aiming at understanding the motivation behind the decisions taken by the decision trees. Indeed, these models are meant to be a support to teachers and students in improving their tasks. For this reason, we are interested in understanding if differences can be observed in different semesters and in different groups of subjects. To this aim, some graphical representations of the decision trees have been provided, together with their explanations in terms of *IF-THEN* rules. Moreover, a feature importance analysis has been conducted to identify the three topmost important features for each algorithm.

4.2 Quantitative Evaluation

Standard classification measures, such as Accuracy, Precision, Recall, F1-score, and Area Under the Curve (AUC) have been used to quantitatively evaluate the classification performance of the considered classifiers. Moreover, for each model, the number of leaves, obtained after the processing of the corresponding tested semester chunk, has been used to evaluate the complexity of the model. Indeed, the more the number of leaves, the higher the complexity of the model and the lower its interpretability.

Tables 2–3 and 4–5 report the results achieved by the experimented tree-based models considering STEM subjects and Social Science subjects, respectively. For each dataset, in the tables, we show the results achieved considering both ANB and MV inference strategies.

Table 2. Comparison of HDT and FHDT in terms of classification performance and model complexity, for the tested chunks on the STEM subset of data, with ANB as inference strategy.

Model	Semester	Accuracy	Precision	Recall	F1	AUC	no.leaves
FHDT-3	2013-J	0.42	0.70	0.42	0.27	0.31	7
	2014-B	0.86	0.86	0.86	0.86	**0.91**	11
	2014-J	**0.90**	**0.91**	**0.90**	**0.90**	**0.91**	11
FHDT-5	2013-J	0.40	0.40	0.40	0.23	0.85	19
	2014-B	0.82	0.82	0.82	0.82	0.85	33
	2014-J	**0.90**	**0.91**	**0.90**	**0.89**	**0.90**	37
HDT	2013-J	0.53	0.72	0.53	0.47	0.56	53
	2014-B	**0.90**	**0.90**	**0.90**	**0.90**	**0.92**	132
	2014-J	0.77	0.77	0.77	0.77	0.79	202

Differences between STEM and Social Sciences data can be observed. Indeed, while for the former using ANB we achieve results better than, or comparable to, using the majority voting strategy, for Social Sciences the majority voting inference method provides better results than the ANB. Moreover, focusing on the different algorithms, for STEM data the different versions of FHDT are more able to adapt the model as new data are available, in fact an increase in accuracy and other metrics is observed from semester 2013-J to 2014-J. For Social Sciences data comparable results are observed with HDT and its fuzzy variant.

Table 3. Comparison of HDT and FHDT in terms of classification performance and model complexity, for the tested chunks on the STEM subset of data with MV as inference strategy.

Model	Semester	Accuracy	Precision	Recall	F1	AUC	no.leaves
FHDT-3	2013-J	0.63	0.75	0.63	0.62	0.88	7
	2014-B	**0.80**	**0.80**	**0.80**	**0.80**	**0.89**	11
	2014-J	0.77	0.77	0.77	0.77	0.87	11
FHDT-5	2013-J	0.41	0.59	0.41	0.27	0.86	19
	2014-B	**0.80**	**0.80**	**0.80**	**0.80**	**0.89**	33
	2014-J	0.77	0.77	0.77	0.77	0.87	37
HDT	2013-J	0.53	0.72	0.53	0.47	0.56	53
	2014-B	**0.90**	**0.90**	**0.90**	**0.90**	**0.92**	132
	2014-J	0.77	0.77	0.77	0.77	0.79	202

Table 4. Comparison of HDT and FHDT in terms of classification performance and model complexity, for the tested chunks on the Social Sciences subset of data with ANB as inference strategy.

Model	Semester	Accuracy	Precision	Recall	F1	AUC	no.leaves
FHDT-3	2013-J	0.63	0.76	0.63	0.63	0.78	7
	2014-B	**0.88**	**0.89**	**0.88**	**0.88**	**0.89**	11
	2014-J	0.73	0.79	0.73	0.74	0.80	11
FHDT-5	2013-J	0.61	0.75	0.61	0.61	0.73	29
	2014-B	**0.88**	**0.88**	**0.88**	**0.87**	**0.91**	30
	2014-J	0.77	0.81	0.77	0.77	0.83	32
HDT	2013-J	0.61	0.75	0.61	0.62	0.86	33
	2014-B	**0.82**	0.82	**0.82**	**0.82**	0.85	102
	2014-J	0.81	**0.83**	0.81	0.81	**0.88**	142

As regards the complexity of the models, it is worth noticing that, obviously, the values of the number of leaves of the trees do not change when considering a different inference method. Indeed, once a tree has been generated using one of the analyzed method, the two different inference strategies have no influence on the complexity. Similarly to what we discussed in [28] and in [25], the FHDTs are characterized by a much lower number of leaves than the HDTs. This factor

Table 5. Comparison of HDT and FHDT in terms of classification performance and model complexity, for the tested chunks on the Social Sciences subset of data with MV as inference strategy.

Model	Semester	Accuracy	Precision	Recall	F1	AUC	nr.leaves
FHDT-3	2013-J	0.76	0.80	0.76	0.77	0.86	7
	2014-B	0.86	0.88	0.86	0.85	**0.90**	11
	2014-J	**0.92**	**0.93**	**0.92**	**0.92**	0.89	11
FHDT-5	2013-J	0.79	0.80	0.79	0.79	0.85	29
	2014-B	**0.86**	**0.88**	**0.86**	**0.85**	**0.91**	30
	2014-J	0.47	0.73	0.47	0.43	0.89	32
HDT	2013-J	0.61	0.74	0.61	0.61	0.84	33
	2014-B	**0.88**	**0.89**	**0.88**	**0.88**	**0.90**	102
	2014-J	0.81	0.83	0.81	0.82	**0.90**	142

is crucial for explainability. Indeed, trees with a big number of nodes and leaves are difficult to understand because the number of returned rules is too big. On the contrary, simpler models lead to simpler explanations (i.e., lower number of rules). FHDT with three fuzzy sets returns the lowest number of rules. Moreover, small differences in the number of leaves are observed across the considered semesters for both STEM and Social Sciences. Differently, an increase in the number of leaves is observed for FHDT with five fuzzy sets and this becomes drastic with HDT. In this case, more leaves, and thus rules, are used to explain the students' behavior in STEM disciplines (about 200) than in Social Sciences (about 150).

4.3 Semantic Analysis

In order to analyze the semantics behind the decision process, the final decision trees obtained with FHDT-3, for both STEM and Social Sciences, have been shown in Figs. 3 and 4, respectively.

Both trees share the same feature as a root, suggesting that, among all attributes, *N. of assessments* is the most important one. They also present the same number of leaves, thus they can be described by the same number of rules. In addition to the aforementioned *N. of assessments* attribute, the relevant features for the STEM subjects are *High education level* and *Homepage*, while for the Social Science subjects they are the *Number of previous attempts* and the *Average score*.

Tables 6 and 7 report the final rules that can be extracted from the trees generated through the FHDT algorithm with 3 fuzzy sets, on STEM and Social Sciences subjects, respectively. It is worth to notice that, as expected, most of the leaves in the trees includes both class labels: each class is associated with a different value of its fuzzy cardinality. Roughly speaking, the higher the value of the fuzzy cardinality of a class, the higher the probability of selecting that

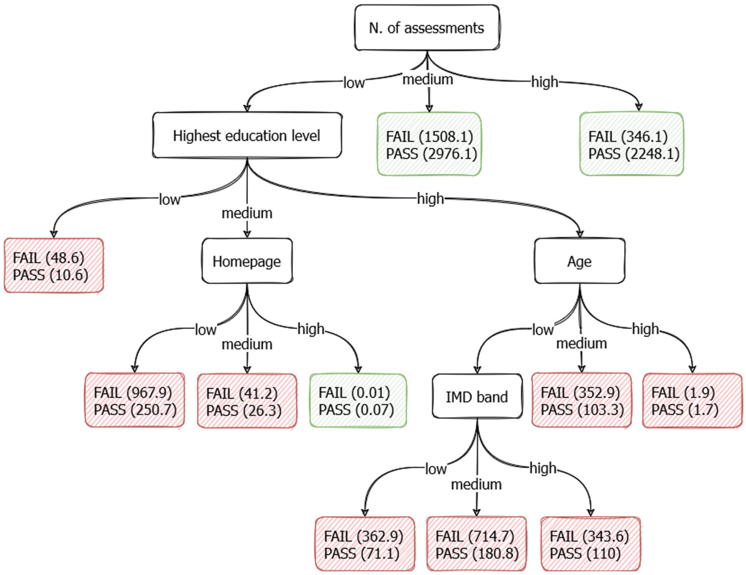


Fig. 3. Final FHDT-3 structure obtained at the end of the incremental learning for the STEM subjects.

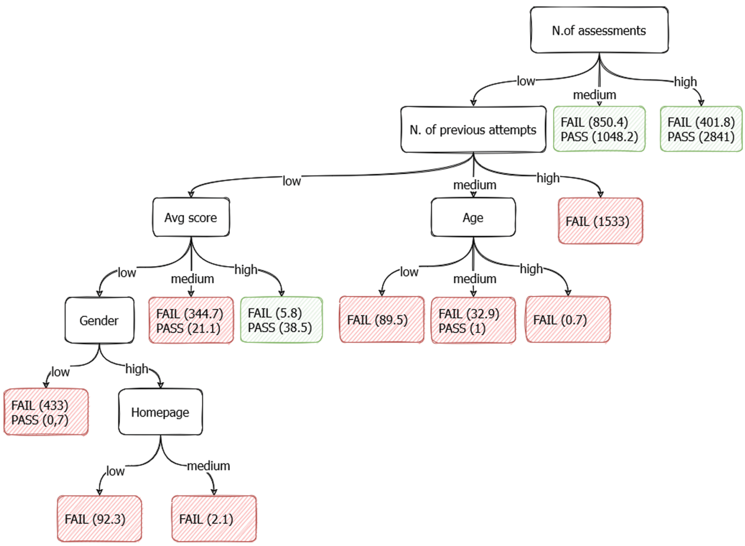


Fig. 4. Final FHDT-3 structure obtained at the end of the incremental learning for the Social Sciences subjects.

class during the inference stage. Thus, each rule in the table has been generated considering as a consequent the label of the class with the highest value of fuzzy cardinality. Rules with the same antecedent and consequent part have been merged.

Table 6. Final rules extracted from the tree generated by the FHDT algorithm, when considering STEM subjects.

1	IF (N. of assessments is MEDIUM) THEN PASS
2	IF (N. of assessments is HIGH) THEN PASS
3	IF (N. of assessments is LOW) AND (Highest educ. level is LOW) THEN FAIL
4	IF (N. of assessments is LOW) AND (Highest educ. level is HIGH) THEN FAIL
5	IF (N. of assessments is LOW) AND (Highest educ. level is MEDIUM) AND (Homepage is LOW) THEN FAIL
6	IF (N. of assessments is LOW) AND (Highest educ. level is MEDIUM) AND (Homepage is MEDIUM) THEN FAIL
7	IF (N. of assessments is LOW) AND (Highest educ. level is MEDIUM) AND (Homepage is HIGH) THEN PASS

The inspection of Table 6 shows that the construction of the tree for the STEM subjects leads to a total of seven rules. Among them, three rules refer to the PASS class, while the remaining ones refer to the FAIL class. Furthermore, it can be highlighted that two out of the three rules related to the PASS class are more general since they are generated from leaves that descend directly from the root node, i.e., the *N. of assessments* feature. On the contrary, rule n. 7 is more specific and involves all attributes of the tree.

As previously highlighted, some specialized rules can be replaced by a more general rule, since they are all related to the same class and branch of the tree. This happens, for example, with rule n. 4, which combines and replaces the following rules:

- IF (N. of assessments is LOW) AND (Highest educ. level is HIGH) AND (Age is LOW) THEN FAIL.
- IF (N. of assessments is LOW) AND (Highest educ. level is HIGH) AND (Age is MEDIUM) THEN FAIL.
- IF (N. of assessments is LOW) AND (Highest educ. level is HIGH) AND (Age is HIGH) THEN FAIL.

Table 7 contains the rules obtained by constructing the FHDT for the Social Science subjects. Similarly to the previous case, there are two general rules (n. 1 and n. 2) that involve the *N. of assessments* feature.

Also in this case, some specialized rules have been replaced by a more general rule. For example, rule n. 5 combines and replaces the following rules:

- IF (N. of assessments is LOW) AND (No. of prev. attempts is LOW) AND (Average score is LOW) AND (Gender is Male) THEN FAIL.
- IF (N. of assessments is LOW) AND (No. of prev. attempts is LOW) AND (Average score is LOW) AND (Gender is Female) THEN FAIL.

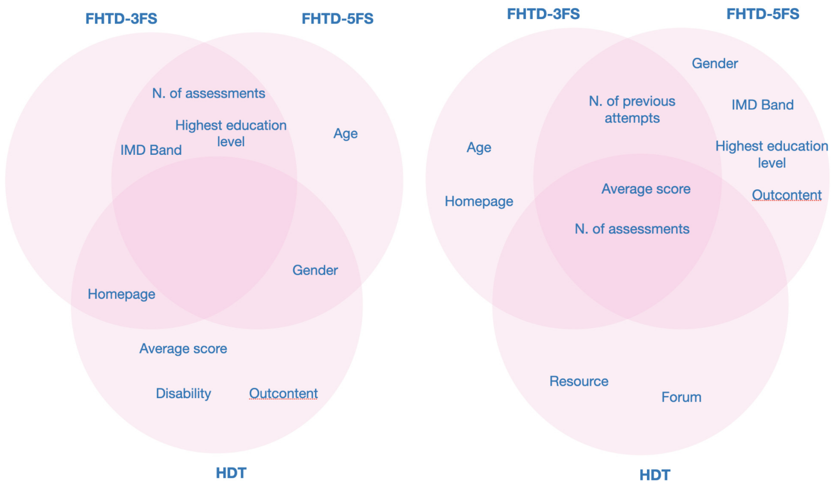
Table 7. Final rules extracted from the tree generated by the FHDT algorithm, when considering Social Sciences subjects.

1	IF (N. of assessments is MEDIUM) THEN PASS
2	IF (N. of assessments is HIGH) THEN PASS
3	IF (N. of assessments is LOW) AND (No. of prev. attempts is HIGH) THEN FAIL
4	IF (N. of assessments is LOW) AND (No. of prev. attempts is MEDIUM) THEN FAIL
5	IF (N. of assessments is LOW) AND (No. of prev. attempts is LOW) AND (Average score is LOW) THEN FAIL
6	IF (N. of assessments is LOW) AND (No. of prev. attempts is LOW) AND (Average score is MEDIUM) THEN FAIL
7	IF (N. of assessments is LOW) AND (No. of prev. attempts is LOW) AND (Average score is HIGH) THEN PASS

Similarly, the general rule n. 4 replaces the following specialized rules:

– IF (N. of assessments is LOW) AND (No. of prev. attempts is MEDIUM) AND (Age is LOW) THEN FAIL.
– IF (N. of assessments is LOW) AND (No. of prev. attempts is MEDIUM) AND (Age is MEDIUM) THEN FAIL.
– IF (N. of assessments is LOW) AND (No. of prev. attempts is MEDIUM) AND (Age is HIGH) THEN FAIL.

Finally, we have carried out a feature importance analysis on both the HDT model and the FHDT models on the two different groups of subjects. Figure 5 compares the most relevant features adopted by the three decision trees, for the two groups of disciplines. As expected, and as already observed from the trees, different subsets of features are considered the most relevant for STEM and Social Sciences subjects, respectively. Moreover, differences can be observed among the three algorithms, with some overlaps. For the Social Science subjects, all the tree models agree in identifying the *N. of assessments* and *Average Score* features among the most informative, meaning that the average score obtained for the intermediate assessments and the number of intermediate assessments is highly correlated with the target class *Final Result*. Indeed, a higher number of intermediate assessments suggests constant study, which is more likely to lead to passing the exams. In general, this result is quite predictable, since intermediate assessments are useful to engage the students by partitioning the required effort. However, it is interesting that the same pattern is not observed for the STEM disciplines. Moreover, it is worth noticing that the two fuzzy decision trees have identified features related to the demographic information as relevant: the students' ages, their highest education levels, the indices of multiple deprivation (IMD Band), the gender. On the contrary, the crisp model has focused more on the student's interaction with the VLE. Further analyses are needed, but this is the first insight suggesting that different learning behaviors are required to study STEM and Social Sciences subjects.



(a) STEM (b) Social Sciences

Fig. 5. Feature importance analysis returned by the three methods (FHDT-3FS, FHDT-5FS, and HDT), for the two groups of subjects: STEM and Social Sciences.

5 Conclusions

In this paper, we have applied two incremental learning algorithms for generating Hoeffding Decision Tree and Fuzzy Hoeffding Decision Tree, respectively, to a publicly available educational dataset. The decision trees have been used for predicting the failing or passing of final exams on the part of students.

We have performed a differentiated analysis considering separately STEM and Social Sciences subjects to verify if different behaviors underlay the study of these two disciplines. Moreover, different semesters have been incrementally analyzed to verify if changes occurred in data distribution and if the evolving algorithms were able to adapt the tree-based models to these changes. From the qualitative evaluation, we have highlighted that quite high classification performance has been achieved by all the experimented decision trees. However, the fuzzy decision trees have shown to achieve the best trade-offs in terms of classification performance and intepretability. Indeed, fuzzy decision trees have achieved results, in terms of classification performance, similar to or better than classical decision trees, while being characterized by the lowest complexity. Moreover, the fuzzy rules that can be extracted from the fuzzy decision trees are characterized by a very high level of semantic intepretability.

Since in the educational domain explainability is crucial, fuzzy decision trees can be suggested as the most relevant ones for the predictive task in this domain. Furthermore, the models generated for the two subsets of data have been compared from a semantic point of view, thus a feature importance analysis has been conducted showing that the fuzzy decision trees mostly rely on demographic features while the crisp model includes click-stream information among the most important features for the classification task.

Finally, the obtained results are encouraging, however future research will involve experts of the educational domain to better study the differences that emerged from the analysis. Moreover, data referring to a wider temporal interval will be considered for further analyses of the use of stream algorithms in the educational domain.

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Psychological Outcomes and Effectiveness of a Collaborative Video-Based Learning Tool for Synchronous Discussions

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Abstract. In the context of digitization and the COVID-19 pandemic, online teaching comes more and more into focus of higher education. Various online learning methodologies such as using videos as a teaching method are promising, but can also create problems in the area of social relations or learning habits. The concept of collaborative learning, especially in an online environment, could counteract these problems. This paper presents a collaborative online learning tool that allows students to get together in learning groups to watch educational videos together. Various functions, such as a chat, help students to communicate with each other. A psychological evaluation was conducted to investigate the effects on students. The evaluation demonstrated positive effects of the tool, since it enhances important psychological processes (like flow and cognitive load) within the learning process. Moreover, its usability was rated as good and participants showed a high usage intention for the tool. Nevertheless, further investigations in long-term learning courses are needed to finally confirm the tool's effectiveness.

Keywords: collaborative learning · online learning · higher education · video learning · psychological evaluation

1 Introduction

The COVID-19 pandemic completely upended the university routine. As a consequence, on-campus and in-person teaching was completely replaced by online teaching. This immediate shift to asynchronous and digital teaching and learning had an impact on students: They were isolated and had limited contact with fellow students [10]. Students also got fewer opportunities to interact and support each other in the learning process [3]. At the same time, the usage of educational videos as a teaching tool became more prominent during the phase of the pandemic. Such videos, where teachers mostly recorded themselves while flipping trough presentation slides, completely replaced on campus lectures. Therefore, students needed to study at home isolated watching those videos while suitable communication and feedback channels for contacting fellow students or teachers were unavailable or hard to access. These circumstances can result in negative

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impacts on the learning success [8], e.g. getting poorer grades in exams. Out of this need, ways had to be found to guarantee the learning success of students during the pandemic despite using remote videos for teaching. In the context of the digitization of teaching it is also important to investigate and develop new concepts and methods to support students in a changing learning environment. For the specific problem of isolated, asynchronous video-based learning at home, the concept of computer-supported collaborative learning might help to counteract the negatives and problems of this teaching method. Collaborative learning as an educational approach not only provides social, psychological, academic and assessment benefits, but can also increase the learning success when studying as a group [9]. Therefore we developed a collaborative framework called vGather2Learn (which in preliminary work was called Learnflix [11]), which supports students in watching and discussing video based lectures collaboratively. By using this tool, students can collaborate on asynchronous teaching content while learning together using a chat and build-in features enabling highlighting and commenting specific sequences in the video. vGather2Learn thus provides students with a form of digital communication and could therefore be a useful tool against isolated learning. To investigate which psychological effects are driving the learning process and the usage of vGather2Learn and what drives learners intention to use the tool in higher education, a psychological evaluation has been conducted using a mixture of quantitative and qualitative methods. Results in terms of usability, cognitive load and flow experience, among others, should create important insights into the use of a collaborative video-learning-tool.

2 Related Work

Educational research suggests that the use of videos for teaching, studying and learning can be meaningful and beneficial. E.g., Merkt et al. investigated the role of interactive features comparing print media with video learning [12]. They found that features that allow micro-level activities (e.g. pausing the videos) could actually show a benefit in learning success compared to using print media for learning. Furthermore Noetel et al. studied video learning at universities [13]. By replacing existing teaching methods with videos, a small improvement in learning success was found and, when using videos as a supplementary teaching tool, a very strong benefit for student learning was found. These results suggest that videos do have the potential to contribute to learning success, which is important for online learning environments, especially due to the changing learning structures triggered by COVID-19. However, social isolation is particularly observed in online teaching. According to Hiltz, this has the consequence that "one of the potential negative effects of online courses is a loss of social relationships and a loss of the sense of community that is usually present on a traditional campus" [6]. Therefore, she presupposes a type of collaborative learning for asynchronous teaching. Laal and Ghodsi examined collaborative learning as an educational approach and categorized the greatest benefits as social, psychological, academic, and assessment benefits [9]. They assume that learning in a group leads to higher success in the learning process and thus in examinations. The benefits and approaches of collaborative learning could mitigate the drawbacks of isolated learning at home and lead to more effective teaching. However, so far no investigations of collaborative video learning have been made and it is still unclear whether this actually has the desired positive effect of if users are also distracted by the tool. Accordingly, the present work investigates the following research questions:

RQ 1: Which psychological effects drive the learning process and usage of a collaborative video learning tool?

RQ 2: What drives learners' intention to use the collaborative video learning tool in higher education?

3 The vGather2Learn Tool

vGather2Learn is a tool for collaborative video based online learning [11]. By using vGather2Learn, it is possible for students to synchronously view online learning videos as a group where individuals are located in different places. The tool is a web application and is integrated in the Moodle learning management system. Teachers of our university use Moodle to distribute their learning material (e.g. presentation slides, videos ...) to their students. Next to the learning material the application vGather2Learn is embedded and can automatically grab the videos of the respective courses and make them available in the tool. vGather2Learn addresses the Moodle API to grab personnel data such as the plain name or the profile picture and make them available in vGather2Learn. This ensures that all students who are members of a course at their university can use the vGather2Learn tool without additional registration. When entering vGather2Learn the user interface opens, which can be seen in Fig. 1.

The figure depicts a learning group's usage example of the tool. Different functions are available for students to learn synchronously together.

They can create their own virtual learning rooms with the button "Create Rooms" to meet with their fellow students or join an existing group with the button "Search Rooms". When joining a learning group, a system message is sent via chat to all active users in the group that a new user has joined the group. To maintain a collaborative video learning session, the video plays (using the "Play" button) and pauses (using the "Pause" button) synchronized for all users. The same is true for the possibility to fast forward and rewind the video. This means that if for instance one user pauses the video, it will be paused for all of them.

In addition, a chat serves as a supplementary means of communication for the tool. Here, students can exchange information about the teaching content. In the pictured example (see Fig. 1) a user asks what "exit code 0" means in the context of the video. Subsequent, a second user gives an answer to this. In addition, users have the chance to mark specific parts in the video either with an exclamation mark or question mark. Here the current position in the

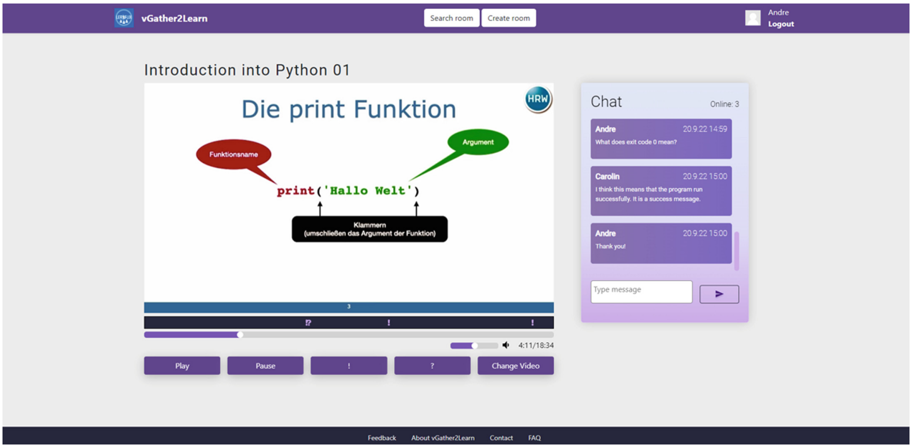

Fig. 1. The user interface of vGather2Learn while watching a video in a learning group

video can be marked and provided with a note. Thus, important points, but also open questions can be marked at various video points. A user creates a note at a video location with the exclamation mark function, which can be seen by all other active users. In Fig. 2 an example of such an interaction is presented. Student could then use these marked video-excerpts in the end of the learning session or after the learning session to discuss or repeat the content in details.

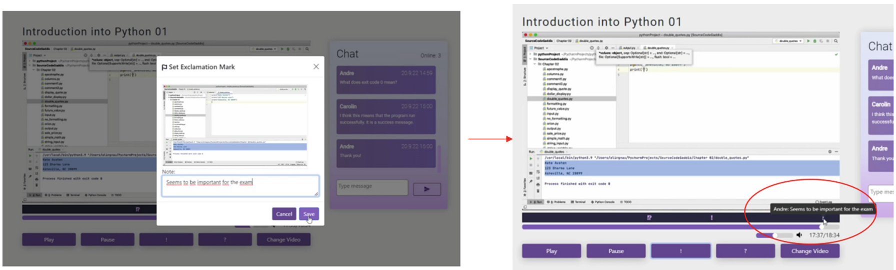

Fig. 2. Demonstration of the exclamation mark function of vGather2Learn

4 Methods of the Evaluation Study

To figure out the potential and the effects of a collaborative online learning tool for videos, an online evaluation study over two weeks was conducted.

4.1 Sample

In total 17 people successfully participated over the study's duration of two weeks. Overall, the sample consisted of 14 men and 3 women with an average age of 21 years ($M = 21.47$, $SD = 2.50$). All participants were students of the University of Applied Sciences Ruhr West and enrolled in the study programs "Human-Technology Interaction" or "Applied Computer Science" and were studying in their second or fourth semester respectively. Participants were divided into seven groups. Each group consisted of 2-3 participants.

4.2 Measures

The measures were provided in an online questionnaire using the online tool SosciSurvey (www.soscisurvey.de). To investigate the effects of the "vGather2Learn" tool on participants, different quantitative scales were used. Standardized questionnaires were used to measure the psychological processes during the learning session, the tools' usability, perceived user experience and feelings within the learning group.

It was tested, whether the tool enhanced the learning process or if it distracted from the actual learning goal by measuring participants flow [14] and cognitive load [7]. To investigate the state of immersion and overload/underload when using the tool, the flow scale according to Rheinberg et al. was used [14]. In particular, the three sub-scales "smooth operation" (FMO; 6 items, e.g. "The right thoughts and movements occurred on their own account.") that indicate if learners are immersed in the operation, "worries" (FW; 3 items, e.g. "I am worried about failing.") representing learners worries during the learning process and "absorbed" (FA; 4 items, e.g. "I don't notice time passing.") that describes the complete absorption in an activity have been investigated. All sub-scales got rated on a 7-pointed Likert scale ranging from 1= "totally disagree" to 7 = "totally agree". To measure the cognitive load during learning, the cognitive load scale by Klepsch et al. [7] was used. Here, the three types of load that can demand working memory resources were examined. First, the intrinsic cognitive load (ICL), which results on the one hand from the complexity of the learning content, which is defined by the degree of element interactivity, and on the other hand from the prior knowledge of the learner, was measured with 2 items (e.g. "This video was very complex."). Second, the extraneous cognitive load (ECL), which results from the design of the learning material, was measured with 3 items (e.g. "The design of this video was very inconvenient for learning."). The last type of cognitive load is the germane cognitive load (GCL), which is defined by the learning-related and learning-promoting load and arises from the construction of schemata and active engagement with the learning content. GCL was measured with 2 items (e.g. "When watching the instructional video, I wanted to understand everything correctly."). Again, a 7-pointed Likert scale ranging from 1= "totally disagree" to 7 = "totally agree" was used.

In order to learn something about the usage intention (UI) of the participants, a scale was self-created. Here, a single item was used "How would you like to use this tool for your personal learning routine in the future?" which got evaluated with a 5-pointed Likert scale ranging from 1 = "not at all" to 5 = "totally".

In addition to these measures, scales from the Technology Acceptance Model (TAM) were used [2]. "Perceived ease of use" (PEOU; 4 items, e.g. "Interacting with the tool does not require much of my mental effort.") measures the user friendliness and "enjoyment" (ENJ; 3 items, e.g. "I enjoy using the tool.") measures the perception of using the tool as pleasurable in themselves.

Moreover, we checked for the social components and investigated how save participants felt in their group during the collaborative learning process (Perceived Safety [4]; 5 items e.g. " In this group, everyone can participate in the chat conversation according to their wishes."). This was rated on a 5-pointed Likert scale ranging from 1= "totally disagree" to 5 = "totally agree".

As a final quantitative tool, the System Usability Scale (SUS) was used to get an impression of the overall usability of the tool [1]. This scale consists of 10 items (e.g. "I find that the various functions are well integrated into the tool.") that were also rated on a 5-pointed Likert scale ranging from 1= "totally disagree" to 5 = "totally agree". The authors of this measurement defined different intervals which roughly classify the usability into ranges from "very bad" to "at best". Additionally, open questions gathered students' personal impressions about the tool and the learning session in more depth. Therefore the following questions have been used: "What are the strengths of the tool?", "What are the weaknesses of the tool?", "Why would you work with the tool?" , "Why would you not work with the tool?" and "General comments". The quantitative methods offer a greater scope for interpretation of the results. Additional information that are not in the scope of the present paper and thus are not reported have been measured (e.g. data about similar learning systems, preferred learning styles in terms of study groups and communication during learning, devices and browsers, experiences with technical problems). Moreover, the tool it self collected log-files about the learning sessions, which are also not analyzed within this work.

4.3 Procedure

The whole evaluation study was conducted online and participants as well as experimenters did not meet in person during the study. Participants joined the experiment in groups who met independently in the vGather2Learn tool at predefined times. All groups participated in two learning sessions within two weeks (one session a week). Besides the overall instructions about the experiment's procedure, no additional instructions about the learning sessions had been given. Thus, participants were free to explore the tool on their own. However, a short tutorial explained the core functions of the tool in the beginning. The learning content was the same for all groups. In week 1 participants had to watch an educational video about the effects of glutamate and in week 2 a video about the effects of light emitted by technical devices e.g. smartphones was presented. The videos originated from the same author and were similar in length and complexity. In both learning sessions, various knowledge questions were displayed in the video, which were to be discussed and solved together by using the chat and question/exclamation mark functions of the tool. Both videos were extracurricular for all participants, to exclude any confounding factors of prior knowledge as the participants differed in their study level. Participants' experiences during the learning sessions got evaluated using online questionnaires. In the first week, participants had to use the tool vGather2Learn with their fellow group members. They watched the learning video together and discussed the questions, the video was asking about. After the first video, a questionnaire had to be filled out. Socio-demographic data was queried and an option to indicate technical problems. Furthermore participants feelings and perceptions as presented in the measures Sect. 4.2 were measured. In week 2 the participants had to use the tool vGather2Learn again in the same groups. In the questionnaire that followed, participants' feelings and perceptions were measured similar to week 1. Before using the tool for the first time all participants gave informed consent and they further got debriefed at the end of the second questionnaire.

5 Results of the Evaluation Study

In the following chapter the results of the evaluation study will be presented. Since the overall assessment is focused on the current work, only the evaluation data of the second questionnaire (after both learning sessions) got analyzed and the evaluations made after the first learning session are not presented in this paper. In the chapter quantitative results, descriptive results, as well as t-tests for every used measurement will be presented to be discussed afterwards. Moreover, qualitative results, impressions and opinions of the participants are shown.

5.1 Quantitative Results

In order to gather a better understanding of the evaluation data, for all quantitative measures, t-tests were used to check if the sample's means significantly differ from the scale's center. If the data differs from center, a higher (than center) value indicates a strong expression (the presence) of the measured component, while a lower (than center) value indicates a lower expression (the absence) of the specific component.

Cognitive Load. The results of the cognitive load survey indicate low intrinsic cognitive load ($M = 3.24$, $SD = 1.32$). A t-test against the midpoint of the scale (which is 4) indicates a significant result ($t(16) = -2.38$, $p = .030$). The numbers suggest that participants experienced low learning task complexity indicating that the learning material was easy to understand. The extraneous cognitive load is also low ($M = 2.31$, $SD = 1.39$) and differs significantly ($t(16) = -5.01$, $p < .001$) from the center. This means that participants are not distracted by the features of the tool due to the low extraneous load. In contrast to ICL and ECL, Germane Cognitive Load is higher ($M = 5.00$, $SD = .89$) than the scales center ($t(16) = 5.46$, $p < .001$). Thus, learners seemed to be engaged and directed their mental resources to the learning process. All means are visualized in Fig. 3.

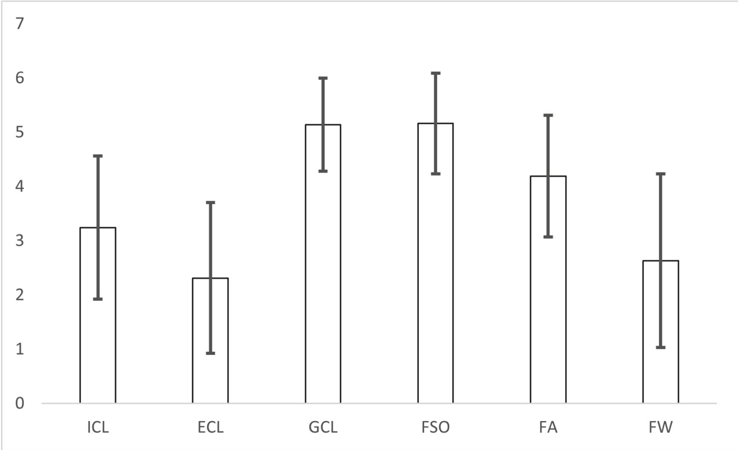

Fig. 3. Visualization of the results of the cognitive load and flow scales

Flow. When looking at the flow scales, a significant high value is found for the "smooth operation" scale (M= 5.16, SD= 0.93), (t(16)= 5.16, p< .001). This means that students experienced a smooth learning process and were immersed in the operation. On the other hand, participants' "Worries" were significantly lower than the scales center (M= 2.53, SD= 1.60; t(16)= -3.78, p= .002). This means that they tended not to be anxious while using vGather2learn. The Absorbed sub-scale did not produce significant results (M= 4.19, SD= 1.12). Again, the results are depict in Fig. 3.

Usage Intention, Enjoyment and Ease of Use. Analyzing the scales for "ease of use", "enjoyment" and "usage intention" rather high values can be observed. The results of the usage intention scale indicate an above-average intention to use the tool (M = 3.63, SD = 1.18). These scales were also tested with a t-test against the scale mean (here scale mean of 3). The result of the usage intention scale is statistically significant (t(16) = 2.20, p = .004). For the enjoyment scale, we found a high value (M = 3.98, SD = 0.95). This result also significantly differs from the scales center (t(16) = 4.24, p< .001). Thus, participants enjoyed using the tool. Furthermore, learners stated that vGather2Learn was easy to use (M = 4.35, SD = 0.44), as statistically significant difference from the scales center was found (t(16) = 12.61, p< .001). Please find Fig. 4 for visualized means.

Perceived Safety. Looking at the "perceived safety" scale, high values (M = 3.90, SD = 0.99) are observable. This result is also statistically significant (t(16) = 3.72, p< .001). Thus, it can be concluded that the learners felt safe in the learning groups and that the learning experience was not impaired by the online environment. Results can be seen visualized in Fig. 4.

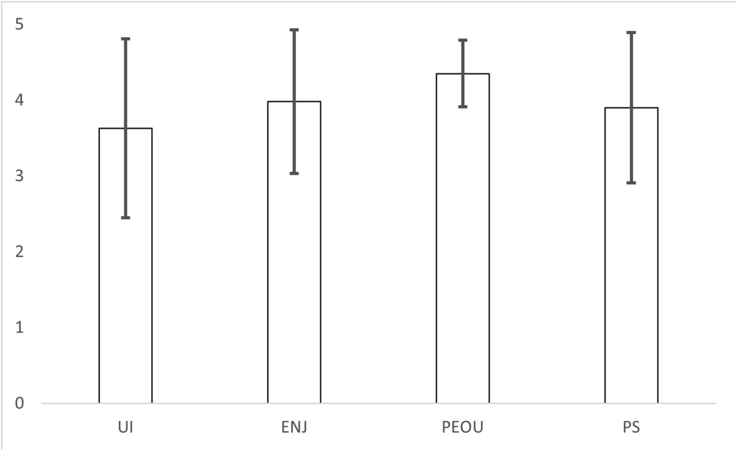

Fig. 4. Visualization of the results of the TAM scales, usage intention and perceived safety scales

System Usability Score. Calculating the SUS score indicates high usability of the vGather2Learn tool ($M = 80.88$, $SD = 14.66$). Considering that the average value of the SUS score is about 68 [1], we conclude that the vGather2Learn online tool was rated in a positive manner. Furthermore, we conclude that the users were able to use the tool well, which is also supported by the other scales described above.

Correlations. In order to identify and understand underlying processes between the psychological indicators, Pearson correlations between all measures have been conducted. Significant, positive correlations were found for Flow-Smooth Operation and Usage Intention ($r(17) = .486$, $p = .048$), Enjoyment and Usage Intention ($r(17) = .785$, $p = .000$), Enjoyment and Flow-Smooth Operation ($r(17) = .652$, $p = .005$), Enjoyment and Flow-absorbed ($r(17) = .625$, $p = .007$), Usage intention and Flow-absorbed ($r(17) = .561$, $p = .019$), SUS Score with Flow-Smooth Operation ($r(17) = .763$, $p = .000$), SUS Score with Usage Intention ($r(17) = .654$, $p = .004$), and SUS Score with Usefulness ($r(17) = .522$, $p = .031$). Negative and significant correlation were found between Flow-smooth operation and Extraneous cognitive load ($r(17) = -.661$, $p = .004$), Flow-absorbed and Extraneous cognitive load ($r(17) = -.583$, $p = .014$), Usage intention and Extraneous cognitive load ($r(17) = -.600$, $p = .011$), Enjoyment and Extraneous cognitive load ($r(17) = -.851$, $p = .000$), Ease of use and intrinsic cognitive load ($r(17) = -.631$, $p = .007$) and SUS Score and Extraneous cognitive load ($r(17) = -.691$, $p = .002$). Table 1 shows the correlation values for all variables.

Table 1. Correlation table for all quantitative measurements

Variable	*ICL*	*ECL*	*GCL*	*FSO*	*FA*	*FW*	*UI*	*ENJ*	*PEOU*	*PS*
ICL										
ECL	.343									
GCL	−.039	−.208								
FSO	−.074	−.661**	.310							
FA	.316	−.583*	.275	.422						
FW	.178	.011	.348	−.010	.147					
UI	−.194	−.600*	.122	.486*	.561*	−.257				
ENJ	−.128	−.851**	.003	.652**	.625**	−.115	.785**			
PEOU	−.631**	−.421	−.081	.217	−.137	−.148	.048	.215		
PS	.001	.144	.165	−.003	−.147	.192	−.122	−.201	−.508*	
SUS	−.249	−.691**	.044	.763**	.323	−.331	.654**	.769**	.443	−.174

**: The correlation is significant at 0.01 level (2-sided).
*: The correlation is significant at the 0.05 level (2-sided).

5.2 Qualitative Results

Qualitative data collected via open-ended questions in the questionnaire were tallied and divided into thematic categories in an exploratory way. Grounding on the data, an inductive coding scheme was created and two categories (with 3 sub-categories each) have formed in the responses: Statements that says that learning alone is more effective and statements that find vGather2Learn useful as a collaborative tool. All statements have been coded by the same coder.

Learning Alone is More Effective. A total of 11 statements were assigned to the category "Learning alone is more effective". This category summarizes statements that indicate that people prefer to learn on their own and that mention specific circumstances that lead to this opinion. The statements could further be gathered in the following sub-categories: *Motivation and Learning Level of the Students*, *General Preference to Learn Alone* and *Complexity of the learning content.* Participants who voted to learn alone and did not want to use the tool in the future, stated that this depends on the *Motivation and Learning Level of the Students* in the learning group. This includes statements such as

> *"If I prefer to work through learning units on my own, e.g. if everyone has a different learning pace in math, it could get annoying if there is a break every minute."*

> *"Because questions from less able classmates could massively reduce my effectiveness."*

> *"The community [is important]. If someone talks alone then the tool is useless."*

Thus, participants feel that by just learning with others, vGather2Learn cannot help them in the learning process. This is mainly due to a fear that other students might hold them back because they are not at the same learning level or show the same motivation. One participant supports this conclusion with the following statement:

> *"The dependency with others is the problem. But that is not a weakness of the tool itself."*

Other participants stated that they have a *General Preference to Learn Alone*:

> *"I find for study content, I learn more productively when I watch videos and learn on my own at my own pace."*

Moreover, the *Complexity of the learning content* is a crucial indicator that drives the preferences to learn alone. Participants see strength in the tool for more complex topics that need to be discussed with co-students. However, in some courses students were only asked to learn the content by heart and in this cases the participants do not see any benefits in the tool:

> *"In lectures like in economics you don't have to understand complex topics, but you have to learn a lot by heart and write texts if necessary. It makes no sense in courses with little complex teaching content. Learning alone is more effective there."*

Learning with vGather2Learn Supports Me in the Learning Process. This category was assigned with 40 statements. These statements show that the majority of respondents find a collaborative online learning tool like vGather2Learn useful. They especially like the *Possibility of Discussion*, that many *Different People Bring Different Interpretations* to the learning process, and that such a *Tool is Easy to Use.* This is reflected by the following example opinions:

> *"It offers a nice learning environment where you can watch videos together, everyone has his peace and can decide for himself if he wants to participate in a discussion or not."*

> *"Within my learning group there are often different interpretations to certain topics, because someone has not watched a video completely or not at all or has understood it differently, vGather2Learn could help to bring homogeneity in the understanding within a small learning group."*

> *"The tool could be the easiest method to watch lecture videos with other students"*

6 Discussion

When considering digitization, researching and developing new digital learning methods is important. The current state of the art enables technologies and tools for digital learning innovations. However, it is important to investigate how digitized learning methods should look like in order to guarantee and even improve an efficient learning process on the one hand. On the other hand, social and psychological consequences of the use of such tools need to be researched and identified. Accordingly, the present paper presented an evaluation of a collaborative video learning tool (vGather2Learn), that enables students to watch and discuss pre-recorded learning videos synchronously. As this tool brings a new approach of learning with videos the effectiveness as well as psychological effects of the tool need to be investigated. An online study with two learning sessions tackled these topics. The above presented results are discussed along the two research questions.

6.1 RQ 1: Which Psychological Effects Drive the Learning Process and Usage of a Collaborative Video Learning Tool?

As the tool offers more options and information (due to the chat option and discussion with other students) than regular video player tools, the effects on participants' cognitive load got investigated. The results show that participants could use the tool with a low extraneous cognitive load, so that they were not overwhelmed or distracted by the functionalities of the tool. In addition participants' germane cognitive load was rather high, which indicates that learners are engaged and direct mental resources to learning process. This could indicate that the tool helps during the learning process to engage into the learning material. However, it is not obtainable, whether the video or the tool drives this effect. Future studies need to investigate this in depth e.g. by comparing videos with different engagement levels and the usage of vGather2learn with a simple video player. The findings are supplemented by the result of the flow scale. Users were engrossed in the use of the tool and were neither afraid nor bored while using it. However, the general absorption in the learning process was not given. This could be due to the fact, that the presented learning material was extra-curricular and had no actual relevance for the participants. Moreover, participants felt save during the usage of the tool. As the social component is a relevant part of the learning approach provided by the tool, this is very important. Our results indicate that the discussion were constructive and that no abuse of the chat function was present. However, it has to be mentioned that all learners knew that the whole conversation was logged (due to the evaluation). Therefore, this kind of observation effect could have influenced the communication style and behavior in a more socially accepted direction. Overall, we conclude that there were few distracting elements in our implementation of the tool, which is reflected by participants cognitive load and flow perception. This could be due to the clear visual design of the tool, but also to the limited functions that participants were given. Further research should confirm this interpretation and identify specific success factors for a low cognitive load and flow experience.

6.2 RQ 2: What Drives Learners' Intention to Use the Collaborative Video Learning Tool in Higher Education?

Participants showed a high usage intention for the presented tool. In particular, we interpret the high results of the "usage intention" scale as meaning that participants can definitely imagine using this tool more often and also in their everyday learning. In line with this, participants report that they enjoyed using the tool and that the tool was easy to use. For the stated enjoyment, it is hard to derive whether this was caused by the tool, the video or the people joining the learning session. However, if the people caused this effect, this supports the effectiveness of the tool, as the tool enables the joined learning session. Looking at the correlations of the psychological effects during the usage and the usage intention, it was found that perceiving a flow state and enjoyment is related to a high usage intention. In contrast to that, having a extraneous cognitive load is negatively correlated with the participants usage intention. Thus, being distracted by the tool is related with a low usage intention. In addition, a good usability according to the SUS score was found in terms of the user interface and user experience. We therefore conclude that the design and the number of opportunities for interaction have been chosen wisely. According to the high SUS Score of vGather2Learn, design principles could be generated that could be transferred to similar systems. These findings are also reflected in the qualitative statements of the participants. It is noticeable that the majority evaluated vGather2Learn as a useful learning tool. In particular, the discussion features were mentioned to be good and useful, which supports the quantitative results. Many participants felt that communication between students should be important and good for their learning success, which is in line with our general approach of a collaborative online learning tool. On the other hand, there was a smaller number of participants who prefer to learn alone and fear being limited by other students. This could be due to different learning styles, the complexity of the learning content or the kind of companionship rather than the tool itself. Since vGather2Learn only supports the principle of learning in groups, people with learning styles that prefer to learn alone might not benefit from it. Practitioners therefore should keep these mechanisms in mind. The effectiveness of a collaborative video watching tool like VGather2Learn strongly depends on the learning groups and the complexity of the presented learning content.

7 Conclusion

This paper presents an evaluation of a collaborative online learning tool for video-based learning. The results indicate that the tool had positive effects on the participants, as it enhanced important psychological processes (such as flow and cognitive load) in the learning process. Furthermore, the usability was rated as "good" in the system usability score rating, thus providing, together with the high usage intention, a framework for design recommendations for such tools. However, this elaboration had a few limitations. The study group was comparatively small and not balanced in terms of gender. Also, the learning material was extracurricular. Thus, in future work, long-term studies would need to be conducted to confirm the results of this study. Since vGather2Learn is fully implemented and ready for use, it is planned to test the tool and collect data at our university for a full semester. Therefore we could reach a higher number of participants and investigate the actual use of the tool in higher education teaching.

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Combining Augmented Reality and Fairy Tales to Teach Science to Primary School Students: Teachers' Experience from the Fairy Tale Science Augmented (FAnTASIA) Project

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Abstract. The use of storytelling has long been covering a wide variety of subjects across different levels of education, from preschool and K12 to professional training. Regardless of the content being taught, storytelling methods are assumed to catch students' attention and involve both their cognitive and affective skills. Educational literature has also collected evidence for effectiveness of the use of augmented reality (AR) technology in promoting greater academic achievement and engagement among students, com-pared with traditional and other digital media-related lessons. Based on existing research, aim of the Fairy Tale Science Augmented (FAnTASIA) project was to design a multi-lingual educational package to integrate storytelling and AR to support the teaching of science concepts and skills in children aged from 5 to 12 years. The present paper first provides a description of the FAnTASIA project and the developed educational package. Following, the paper presents the research design implemented to evaluate the effectiveness of the package in promoting children's knowledge and cognitive skills and users' (students and teachers) satisfaction with its use. In this regard, the final section describes teachers' experience with the use of the educational kit from the results of a questionnaire specifically administered to this purpose.

Keywords: Educational Fairy Tale · Augmented Reality · Storytelling · Science Teaching · Primary Education · Scientific Skills

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1 Introduction

The use of storytelling has long been covering a wide variety of subjects across different levels of education, from preschool and K12 to professional training [1]. While research addressing this topic in K12, especially in primary education, has generally focused on the teaching of literacy skills and language acquisition [2], some attempts have been done to exploit the opportunities the use of storybook and tales has to offer for the teaching of STEM subjects [e.g., 3, 4]. Regardless of the specific content being delivered, storytelling methods are assumed to catch students' attention and involve both their cognitive and affective skills [1].

The potential power of AR as a cognitive and pedagogical tool is its ability "to enable students to see the world around them in new ways and engage with realistic issues in a context with which the students are already connected" [5, p. 86]. AR, while the student interacts with digital information embedded within the physical environment, improve scaffolding and facilitate participatory and metacognitive learning processes such as authentic inquiry, active observation, peer coaching, reciprocal teaching and legitimate peripheral participation with multiple modes of representation (Ibidem).

Educational literature has also collected evidence for effectiveness of the use of augmented reality (AR) technology in promoting academic achievement and engagement among students across several subjects, compared with traditional and other digital media-related lessons [6–8]. Primary education resulted to benefit most from the use of AR solutions and natural sciences, mathematics, and statistics were the most widely subjects taught using AR. Moreover, research has identified *in situ* interactive visualization as a common learning benefit coming from AR that seem to help students learn spatial relationships, such as astronomy configurations or spatial configuration of human organs [9].

Based on evidence provided by existing research, aim of the Fairy Tale Science Augmented (FAnTASIA) project [10] was to design an educational package that would integrate storytelling and AR technology to support the teaching of scientific concepts and skills in children aged from 5 to 12 years. The hypothesis guiding the design and development of the FAnTASIA educational kit was that embedding AR support to the didactic use of narration would enhance the effect of the educational intervention on children's attitude towards learning, engagement, and achievements.

The present paper focuses on the description of the experience of a sample of teachers' in using the fairy tale included in the educational kit, with and without the support of AR content respectively, for instructional purposes. Before presenting the main results, this contribution briefly introduces.

1) the FAnTASIA project and the components of the educational package, and
2) the research design implemented to evaluate the impact of the package in promoting children's academic outcomes.

2 The FAnTASIA Project and Its Educational Package

The FAnTASIA project is an Erasmus + project co-funded by the Erasmus + Programme of the European Union; it started in November 2019 and is planned to be finished by October 2022. The project activities have been implemented by a consortium that included European public universities and research institutions, and a private company.

Main aim of the project was to develop a multilingual (i.e. English, Greek, and Italian) educational package for use in teaching of basic scientific concepts and skills to primary school children aged from 5 to 12 years. The kit was designed with the intent of facilitating children's learning of the following scientific concepts: the concept of the spherical earth, as a planet moving around itself and the sun; the phenomenon of the day/night cycle; and the explanation of floating & sinking of solid objects in the water. Additionally, the didactic activities included in the package were designed in such a way that learners are prompted to develop mastery of the basic principles guiding scientific thinking that is assumed to help them better evaluate and reshape their beliefs concerning real-world phenomena.

The educational package was developed keeping in mind the idea that it could be easily used by children in science classrooms as well as at home only with the support of an adult – teacher, professional educator, or parent/guardian - regardless of their training and/or educational level. The package includes 1) a fairy tale, 2) a mobile application powered by AR content, and 3) a user manual that was specifically created to help and guide adults in maximizing the benefit coming from the educational activities. The following subsections provide a brief description of each the components of the package introduced above.

2.1 The Fairy Tale

The fairy tale "*On the Road to the Sun Palace*" [11] comprises wight chapters telling the story of an illiterate young shepherd who, during his adventures, will find the answers to many questions concerning the physical world. The adventure of the fairy tale hero, Yiannis, starts when he makes the bold decision to travel west to find the Palace of the Sun. During his journey, Yiannis faces withs several problems and difficulties that he manages by observing the environment around him, conducting experiments using simple materials, and having discussions with people he meets.

Children using the fairy tale with the support of an adult are expected to follow Yiannis' journey by doing similar activities as indicated by consecutive numbering in the text. Each number corresponds to an activity described in detail in the second chapter of the "Fairy Science Self-Training Manual". Children can thus discover along with Yiannis and step by step the correct answers to the faced difficulties and learn new scientific concepts. Besides, the fairy tale book is accompanied by eight audio files, corresponding to the eight book chapters, including the narration of the fairy tale and background sounds.

The book also includes three wide images which can serve as marker to be scanned using the cam of a mobile device in order to visualize AR content and interact with it. The next section introduces the FAnTASIA application that was designed and developed for the use by children to superimpose AR educational content over the three images included in the fairy tale.

2.2 The AR Application

The augmented reality content, supported by the FAnTASIA mobile application [12], allow children to visualize an additional realistic environment to test and adjust their hypotheses about the studied phenomena. To this purposes, three AR scenarios have been developed to support children's learning of the proposed scientific concepts through the interaction with the different AR objects specifically created within each scenario. The scientific concepts addressed in the fairy tale that can be augmented using the application are as follow:

- floating and sinking,
- shape of the earth,
- day/night cycle,
- and gravity.

Each AR scenario can be activated using the cam of a mobile device to scan one of the three pictures included in the fairy tale at specific points. Figure 1 shows the first image that allows the activation of AR content developed to support children's learning of floating and sinking of solid objects in water.

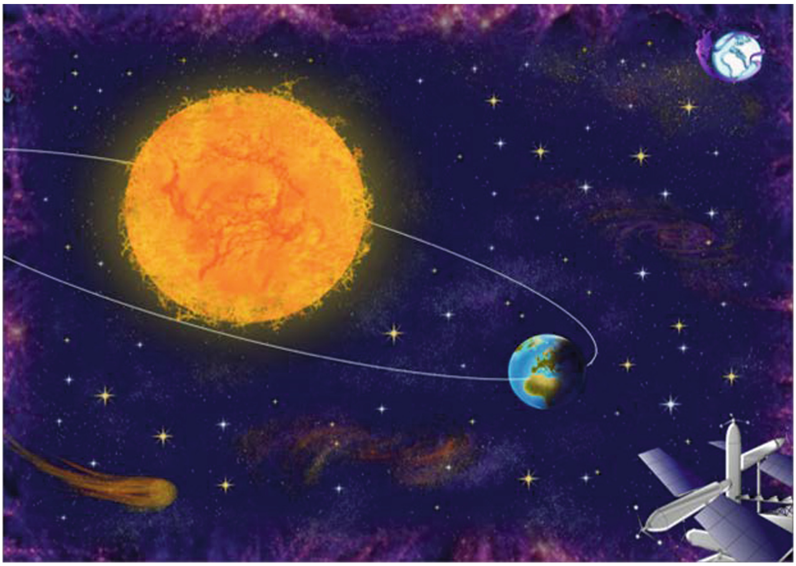

Fig. 1. Example of marker included in the fairy tale text to activate AR content

Once activated, the scenario consists of a list of questions related to one of the scientific concepts. Children are asked to interact with the AR objects and then provide their answer; in case of wrong answer, children are asked to use again the AR scenario to give an additional answer as an alternative hypothesis to be tested.

2.3 The User Manual

As previously stated, the FAnTASIA educational kit was developed with the purpose to be easily used by children with the support of an adult both in formal and informal settings and regardless the adult's training or educational level. To this aim, a user guide was realized to guide adults in taking full advantage of the fairy tale. The user guide "*Fairy Tale Science Self-training Manual*" can be downloaded from the project digital repository [13].

The manual comprises three chapters. The first chapter provides a description of the theoretical framework that guided the development of the educational kit, with specific attention given to the difficulties that students typically encounter in learning the specific concepts addressed by the kit. The second chapter describes in detail scenarios for the educational use of the fairy tale with a set of educational activities that children will be asked to perform with the assistance of the educator/guardian. Most of the proposed activities have been designed following research findings and already evaluated in real science school environments during other research projects. The last chapter presents a set of music and drama activities to foster children's learning and especially the youngest in age.

3 The Pilot Study: Evaluation of the FAnTASIA Educational Package

As already stated in the Introduction section, the assumption guiding the development of the FAnTASIA educational package was that combining storytelling, as a long-standing effective pedagogical method, with new technological solutions represented by AR content could positively impact learners' acquisition of scientific concepts and skills, and their motivation towards science learning, regardless of educational settings. The present section describes the research design implemented to evaluate the effectiveness of the FAnTASIA package in promoting children's knowledge and cognitive skills and their development of a positive attitude towards science learning.

More specifically, the research questions the project sought to answer were expressed as follow:

- can a fairy tale be used as a teaching tool foster children's scientific knowledge and skills, engagement, and attitude towards science?
- does embedding AR content enhance the effect of the traditional (i.e. not augmented) fairy tale on children's scientific knowledge and skills, engagement and attitude towards science?

  and finally,
- are users (children, teachers, and other significant adults) satisfied with the use of both the augmented and not augmented educational packages?

3.1 Research Design

For the purposes of the impact evaluation, a pre-test/post-test quasi-experimental between-group research design was used [14]. Students attending primary schools across

Greece and Italy were recruited for participating in the study; a total of 258 students from 12 4th-grade and one 1st-grade Greek and Italian classrooms were enrolled in the study; 10 teachers were asked to deliver the lessons planned for the educational intervention that required the use of the educational package. Specifically, classrooms were divided into two educational conditions which used the educational package with and without support of augmented reality content, respectively.

3.2 Measures

In order to assess students' performance, a list of outcome measures was selected and administered before (pre-test administration) and at the end of the educational intervention (post-test administration). The measure comprised two questionnaires and a test:

a) a questionnaire containing multiple-choice questions assessing children's knowledge of the concepts of the earth and the sun, the day/night cycle, and floating and sinking of solid objects; questions were derived and/or are adapted from published scientific papers [e.g., 15, 16] in the relevant knowledge domains (i.e., Physics and Earth Science);
b) the Scientific Inquiry Cylcle Test [17], assessing children's scientific reasoning, operationalised as the understanding and application of the steps of the scientific inquiry cycle. The test consists of 15 items that are dichotomously scored (wrong vs. correct answer);
c) a questionnaire assessing children' attitude towards science learning, comprising a selection of items from the Student Questionnaire of the Trends in International Mathematics And Science Study 2015 Context Questionnaires [18];
d) a questionnaires comprising items rated on a Likert-type scale, administered to teachers, to assess students' behavioural, emotional, and cognitive engagement with the FAnTASIA set of educational activities for both the conditions (use of educational package with and without support of augmented reality content);
e) a questionnaire assessing students' levels of satisfaction with the use of the educational package with and without AR (i.e. perceived ease of use, enjoyment, usefulness) depending on student experimental allocation to one of the two conditions.

With regard to the evaluation of teachers' experience, teachers were asked to complete a final questionnaire at the end of the intervention. The questionnaire included a set of questions, rated on a Likert-type scale, assessing 1) their overall experiences with and 2) the perceived learning impact of the FAnTASIA educational packages (with and without the support of AR technology respectively). A closing open-ended question was added to the questionnaire to collect teachers' global evaluations of the FAnTASIA package. The Results section of the present paper describes teachers experience with the educational kit focusing on results from the final questionnaire.

3.3 Implementation of Impact Assessment

Before any activity related to the impact assessment was begun, participating teachers underwent a training session on the use of the educational package and the theoretical framework behind its implementation. More in detail, teachers received instruction on how to use the fairy tale and all the related didactic materials either with or without the additional support of the AR application; an introduction of structure and functionalities of the AR application was also provided. Teachers were finally introduced with the research design, and specifically with an explanation of the selected outcome measures and timing of administration. Training sessions were delivered online to both Greek and Italian teachers.

As soon as the training was completed, students underwent pre-test administration of outcome measures. After pre-test measurement, classrooms involved in the project activities implemented an educational intervention according to the specific condition they were assigned to (i.e., FAnTASIA augmented vs. FAnTASIA non-augmented). Regardless of the condition, the intervention included eight sessions, each lasting 90 min; teachers were instructed to deliver each session within the same week, either in a single administration or divided into parts. Post-test administration of outcome measures concluded the implementation of impact assessment.

4 Results: Evaluation of Teachers' Experience

Ten teachers, five from each country involved in the project activities, were enrolled in the study and completed the questionnaire administered at the end of the intervention to assess their experience. A total of 13 questionnaires were completed, 7 for the augmented and 6 for the non-augmented condition, one for each classroom that was enrolled in the project.

4.1 Results the Likert-Type Questionnaire

This section reports results from the analysis of the Likert-type questionnaire; the questionnaire included items asking teachers to provide a rating of their experience with the educational kit, or supported by AR technology or without its support, across the following dimensions:

- quality of students' interaction with the educational package (i.e., fairy tale, educational activities, and AR application, on the basis of the experimental condition);
- quality of their own interaction with the educational package;
- perceived impact of the educational package.

Figure 2 summarizes rating of students' interaction with the educational kit, in terms of ease of use and enjoyment, that were made by teachers who conducted the FAnTASIA intervention in the AR condition. Overall, teachers reported that their students found it quite easy to use the AR application and manage the activities of the educational kit; they also found their students strongly enjoying the educational activities enhanced with the use of the AR application. Similarly, students interacted with the activities included in the educational kit without relevant difficulties in the opinion of most of the teachers who used the educational package without AR support; again, teachers reported a high level of students' enjoyment while interacting with the educational activities (Fig. 3).

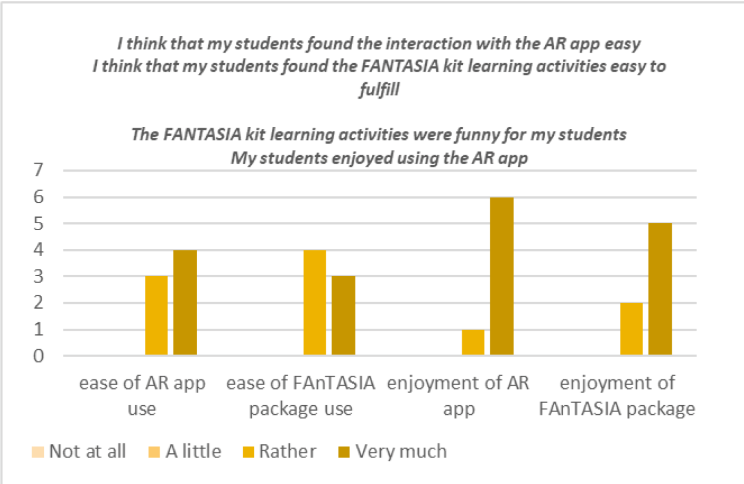

Fig. 2. Teachers' perceptions of students' interaction with the educational package activities and AR app (AR condition).

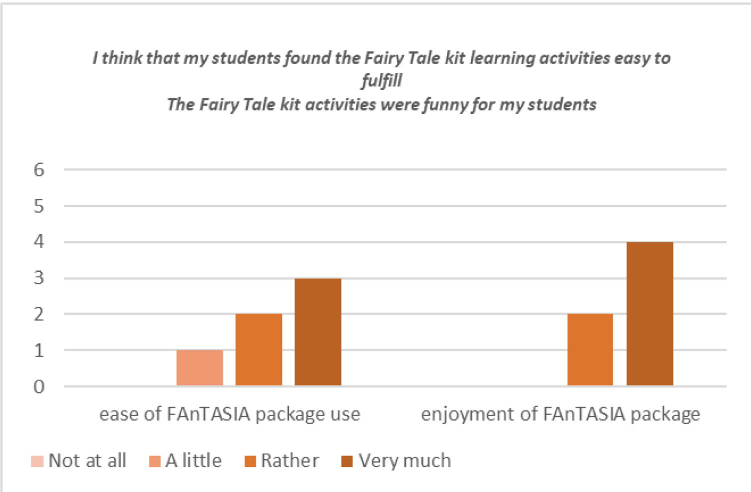

Fig. 3. Teachers' perceptions of students' interaction with the educational package activities (non-AR condition).

The following Figs. 4 and 5 summarizes the results from items asking teachers to assess their own interaction with the educational package either supported or not by AR content. In both the educational conditions, most of the teachers reported their experience with the package to be highly appreciable, and overall found the educational materials quite manageable. Mirroring these results, teachers who used the AR application reported a very enjoyable experience with the application that was in general rated as easy enough to use.

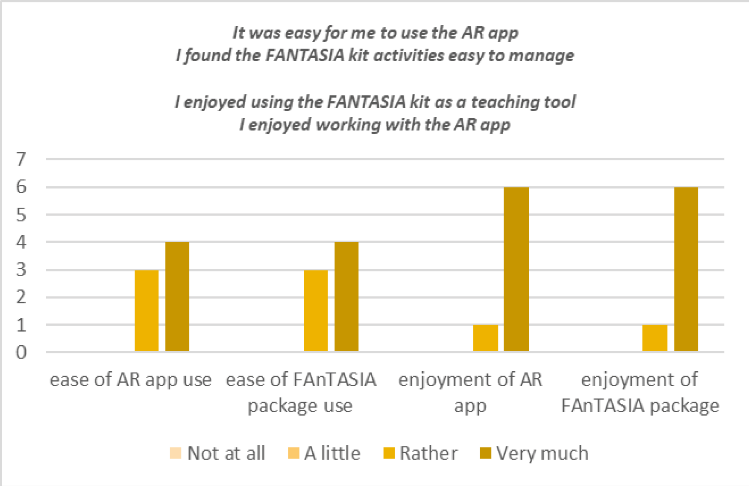

Fig. 4. Teachers' perceptions of their own interaction with the educational package activities and AR app (AR condition).

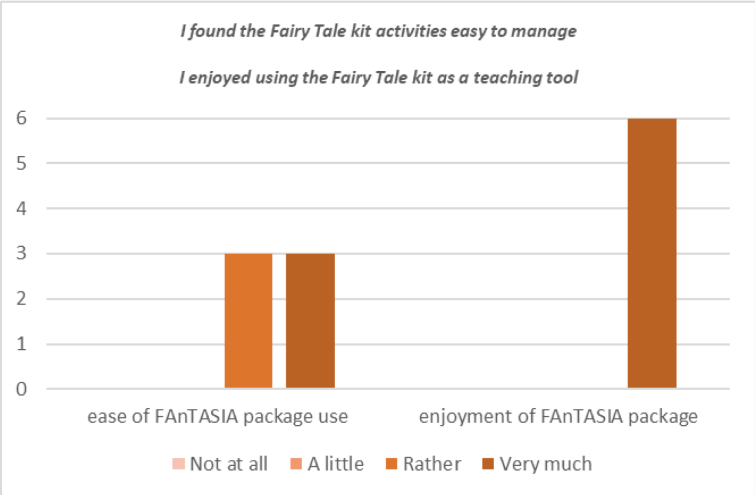

Fig. 5. Teachers' perceptions of their own interaction with the educational package activities (non-AR condition).

Overall, as shown in Figs. 6 and 7, teachers involved in both the experimental conditions recognised the positive impact of the educational kit, augmented or not, in promoting their students' learning of scientific concepts and a positive attitude towards science learning. They also considered the educational kit as a useful tool to stimulate their motivation to learn and foster their attitude towards peer collaboration.

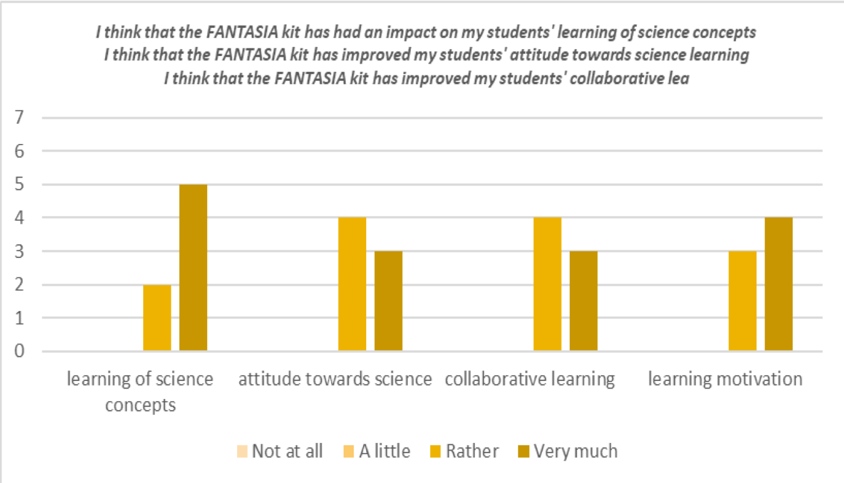

Fig. 6. Teachers' perceived impact of the augmented educational package on students' learning

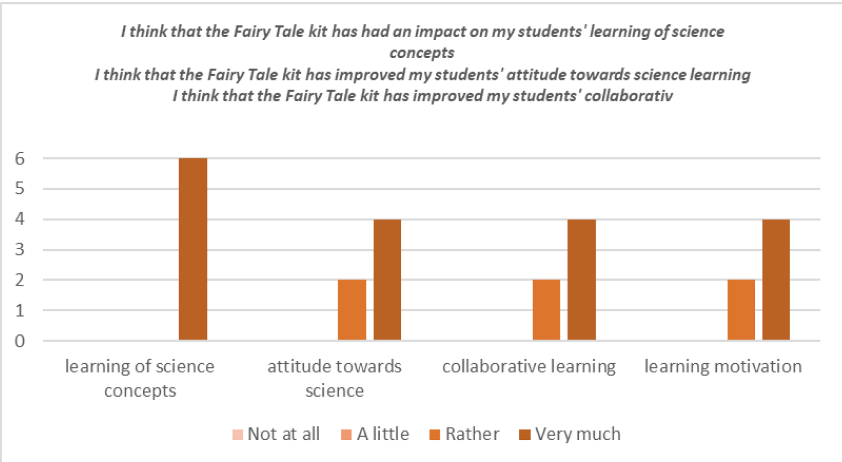

Fig. 7. Teachers' perceived impact of the non-augmented educational package on students' learning

4.2 Results from Open-Ended Question

The present section summarizes results from the final open-ended question asking teachers to provide a brief overall assessment of the educational kit they used during the impact assessment activities enhanced by content supported by the AR application.

Teachers' opinion about the didactic fairy tale and the complementary educational material was generally positive for both the augmented and non-augmented educational kit. First, teachers appreciated the structure the educational materials were organized with within each lesson, and in this regard one of them stated:

> "*It is a completely designed teaching material appropriate for students of all kinds of learning types (such as those who learn better when they listen something or watch something or use their hands etc.)*".

Another teacher added:

> "*the lessons and their very meticulous explanations, and the user manual as well as accompanied and supported me throughout*".

Teachers also recognized the opportunity the intervention gave to the students to learn basics of scientific reasoning while collaborating with their peers, for example:

"*The material gives the opportunity to the students to collaborate, exchange ideas, make hypotheses and test them by doing experiments and helps them change their beliefs based on the experimental results*", and

> "*It puts them in the process of dialogue and collaboration of experimentation and exploration*".

Interestingly, one teacher said:

> *"we also noticed that the project appears to be inclusive, even the student with disability participated with motivation in all the proposed activities",*

thus highlighting the opportunity the educational kit provided to sustain participation of students with disabilities in the educational activities.

Most of the teachers participating in the project, regardless of the educational condition they were assigned to, recognized the value of a didactic use of the fairy tale in stimulating children's motivation towards science lessons and their engagement with the lesson. Teachers stated:

> *"the children were taught science concepts with the help of a fairy tale, which motivated their interest and attention in the lesson"*, and.
>
> *"the Fantasia kit definitely had a positive effect for pupils on science learning in that through the playful aspect it stimulated more attention, curiosity and involvement".*

With specific regard to the incremental contribution of the AR scenarios, teachers considered the AR scenarios as an effective and highly engaging tool for science teaching; for example, two teachers stated:

"pupils were motivated, interested and enjoyed the use of AR; their involvement and learning was from an emotional, cognitive and cultural point of view", and.

"*the use of technology and easy access to the application helped my students understand the concepts and experiment safely*".

It should be note that one of the involved teachers reported about the need for experiments with real objects to be conducted along with AR use to foster learning consolidation:

"*the use of technological tools certainly acts on pupils' interest by increasing their attention and concentration … I think it is also necessary to use the Kit* [augmented] *in combination with real experiments for further consolidation of learning*".

5 Conclusions

Overall, the educational kit and the activities included in the user guide were managed without any relevant difficulty by the students involved in the project in the opinion of their teachers. With specific regard to the AR application, this result is a consequence of the design efforts geared toward the development of an interface that would ensure the possibility of interaction with the AR objects while maintaining ease of use. On the other hand, students were guided by their teachers during the educational activities and teachers were trained to use the kit and the AR application before the educational intervention was begun. This training allowed teachers to efficiently guide their students during the educational activities. In this regard, results from this paper also suggest that teachers themselves considered the educational kit and the AR application easy to use and manage in their classrooms.

Teachers also recognized that the use of both a fairy tale and AR technology for educational purposes represented an effective tool to engage students and maintain their attention focused on the educational activities. This result is in line with findings from existing research on the educational use of both storytelling and AR technology that confirm their effectiveness in stimulating students' motivation and engagement during instructional activities [1, 7].

Overall, the teachers' feedback described in this paper may be relevant for the design of effective training interventions targeting students attending master's degrees, pre-service teachers, and teachers in training for professional development programs.

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Thinking Groups and the Development of Affective Problem-Solving Competencies in Online Learning Environments at the University Level

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Abstract. We present the first findings of an online problem-solving experience for undergraduate students attending a topology course within a Bachelor of Mathematics course. The aims were to promote the construction of problem-solving competencies by using cognitive roles within *Thinking Groups* (TG) with a magnifying lens on the affective level. We define the notion of Thinking Groups and the derived TG model and present an application. The key idea behind personifying cognitive functions with cognitive roles in a problem-solving process represents the starting point of ongoing research into the construction of the problem-solving competencies of undergraduate students and began with an analysis of some metacognitive aspects that students experienced by playing these roles. Each individual role corresponds to a cognitive function coming into play when a mathematician faces a problem. In turn, each collective role corresponds to a problem-solving thinking process performed by a Thinking Group. To shed the light on the emotional outcomes of students and on the impact of the use of online learning environments on the affective dimension, we focused our qualitative analysis on the emotional experience of students both with respect to structured problem-solving activities and digital tools, to understand if and how they fostered the conditions for developing emotional competencies according to Goldin's idea of affective competencies.

Keywords: University Mathematics Education · Problem Solving · Topology · Roles · Thinking Groups · Affect

1 Introduction and Research Context

Problem solving has an undisputed educational role in mathematics education as it provides experience of those key processes that are involved in exploring, conjecturing, proving, representing, and monitoring [1, 2]. A problem-solving process develops at different synergistic levels which are each related to multifaceted competencies: metacognitive [3], cognitive, and affective. The issue then arises of how to achieve these competencies. Mathematics education research suggests that asking students to generate their own

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examples of concepts and autonomous proofs represents an important problem-solving learning strategy promoting the acquisition of such competencies.

At the university level, the study of topology topics fits well in this panorama [4]. Exploring, conceptually understanding, arguing, conjecturing, and discovering the key idea of a proof in topology allow undergraduate mathematics students to engage in real problem-solving processes. In particular, the production of examples to internalise a concept [5, 6] and to improve the student's autonomy to produce proofs about these concepts [7], requires the activation of significant cognitive functions that are simply the mental processes [8] coming into play during a problem-solving process. Hence the need to design problem solving activities in such a way that they contain suitably packaged ingredients (tasks, methodologies, environments) in order to improve the student's personal experience on cognitive, metacognitive, and affective levels.

In this regard, inspired by a national research project [9], the key idea of personifying the problem-solving process through cognitive roles [10] within a *Thinking Classroom* [11] represents the engine of ongoing research into the construction of the problem-solving competencies of undergraduate students and started with an analysis of some metacognitive aspects that students experienced by playing these cognitive roles [12]. Each individual role is associated with a cognitive function coming into play when a mathematician faces a problem: the Boss, Promoter, Critical Mind, and Blogger. Each collective role, on the other hand, is associated with a co-thinking process, engaging a Thinking Group as a Solver or as an Onlooker.

The new idea of a *Thinking Group,* which is the basis of our didactic online experience, originates from the fusion of the notion of a *cognitive role*, first advanced in a paper by Albano, Coppola, and Dello Iacono as part of the national Digital Interactive Storytelling in Mathematics (DIST-M) project [9], with that of a *Thinking Classroom* (TC) introduced by Peter Liljedahl [11]. According to Liljedahl, a TC is.

> "*a space that is inhabited by thinking individuals as well as individuals thinking collectively, learning together and constructing knowledge and understanding through activity and discussion*".

In our model, named TG, Thinking Groups are groups playing a collective role in which each member plays a cognitive role. Albano, Antonini, and Miranda [12] spoke of "thinking groups" (Thinking Solver Group and Thinking Onlooker Group), as groups where each member performed an active function in solving a problem.

Recent research has paid more attention to the impact that the emotional experience of students studying mathematics at university could have on their academic learning journey. We have here focused on the role of emotions in mathematical problem solving at the university level, applying a model integrating two constructs: a cognitive role and TC. This research was part of a project that started with the study of the metacognitive impact of the roles played by the students both on the solving-problem process and their own experiences, that is the students' declarative knowledge and awareness of the cognitive functions they experienced by playing the corresponding roles during the activities.

Therefore, we proceed the study focusing on the affective level, based on beliefs, emotions, attitudes, values, motivations, and all other emotional aspects influencing the decisions and actions of students, all dealing with affective competencies. Affect plays a prominent role in problem solving and is a complex research theme due to its polyhedral nature [13]. An exhaustive paper helping to understand this complexity is represented by Research Forums [14], which enable the discussion of some theoretical frameworks of affect in mathematics education. McLeod [15] identified three concepts used in the research into affect in mathematics education: beliefs, attitudes, and emotions. Emotion was probably the most fundamental concept when discussing affect. Beliefs were seen as the most 'cognitive', and emotions as the least so. Attitude stood between beliefs and emotions, according to the three dimensional model for attitude towards mathematics (TMA) introduced by Di Martino and Zan [16]. De Bellis and Goldin [17] added a fourth element, values. Most research on affect in mathematics has used one or more of these four concepts (the tetrahedron model). Each vertex of the tetrahedron (emotions, attitudes, beliefs, and values) may be understood as interacting dynamically with the others in an individual.

Our research dealt with understanding the interactions between affect and cognition. It is well known that emotions are not only consequences of cognitive processing, but they also affect cognition. We referred to some characteristics of Goldin's theoretical framework according to which affect was a representational system parallel to cognitive systems that encoded important information regarding problem solving and was especially relevant to *the person in relation to the Mathematical activity* [18]. According to Goldin's idea, affective competencies "*refer to the capabilities of an individual to make effective use of affect*" [19]. Goldin's hypothesis is that meta-affect is *the most important aspect of affect.* It is what enables people, in the right circumstances, to experience *fear* as *pleasurable.*

Assuming that cognitive and affective aspects were intertwined, we faced the issue of promoting the development of the problem-solving competencies of students by offering them group-structured opportunities which allowed them to practice and become aware of their cognitive and affective processes. They were thus able to monitor and coordinate affect and cognition, and to develop meta-affective and affective competencies.

2 Theoretical Framework and Research Questions

The theoretical framework inspiring the design of this study originated from the interwining of the TC model with the DIST-M one through the personification, in a Thinking Group, of the cognitive functions being activated when a mathematician faces a problem. To analyse some emotional outcomes coming from students' protocols, we referred to the theoretical framework concerned with affect in mathematical education as a representational system.

The new idea of Thinking Groups (TG), fundamental in our problem-solving experience, joins the notion of a cognitive role, first advanced in a paper by Albano, Coppola, and Dello Iacono [10] as part of a national project, the DIST-M, with the TC concept introduced by Peter Liljedahl [11].

In the paper [10], the authors started with the question: *What cognitive processes should be activated when a mathematician faces a problem?* They then outlined some mental processes that mathematicians should activate when solving a problem (e.g., looking for paths, questioning themselves, organising themselves, systematising the findings…), and identified each cognitive function with a cognitive role to personify. In the model, each student had a specific role in relation to which specific actions/processes had to be performed according to the cognitive function they personified:

Boss. The Boss managed the activity from every point of view (organized actions, ensured participation…).

Promoter. The Promoter provided insights to promote a path that, starting from and manipulating prior mathematical knowledge (concepts and propositions), led to the construction of examples, and conjectured and outlined a solving strategy. In case of uncertainties, they asked for the teacher's help.

Critical Mind. The Critical Mind questioned the truth of the arguments and the validity of the answers proposed by the group, with the aim of corroborating their findings.

Blogger. The Blogger collected and rearranged everything that emerged from the discussion, to draw up a document that contained all the arguments, observations, doubts, questions, and answers.

Any cognitive role was played on two levels: that of an Onlooker or a Solver. Each subgroup of students had a specific group role in relation to which cooperative actions/processes were to be performed with respect to the problem needing a solution:

Solver. The Solvers discussed and built the scaffolding for a solution. Then, they drew up a collective document and explained how the construction of the answers took place.

Onlooker. The Onlookers critically observed the Solver group throughout the problem-solving activity and wrote all the observations on the path and the strategy used by the Solver group, and on other possible paths, accurately motivating their choices.

Each group was engaged in a TC [11], a space inhabited by thinking individuals performing a cognitive role as well as individuals thinking collectively and performing a group role, to discuss and construct the solution in a problem-solving activity. This allowed the groups to learn together and construct knowledge and understanding through activities and discussions.

The notion of Thinking Group thereby took shape**.** We could say that:

A Thinking Group is a TC in which each student performs an assigned cognitive role, as a Solver or as an Onlooker.

We associate a new model with this definition we call TG model. The action of assigning a role could be compared to the gesture of assigning a chalk of a specific color, according to the role. Unlike what happened when applying the TC model, where the teacher decided when and to whom to assign the chalk to write on a vertical board and when to pass it on to another, in our model (TG) it was not the teacher who handed over the chalks, but the assignment was determined by the variation of the activities, since the roles and so the colored chalks rotated among the students of the group, according to a planned program. So, while in the TC model there was only one performer, changing according to the teacher's choice which was made on the moment, it was as if we were passing to each member of the Solver group a chalk of a certain color, and this color changed varying the activity. So, unlike it happens in DIST-M model, in TG model, to foster the awareness of all the cognitive functions, the students changed both individual and collective roles, as well as the problem to be focused on with each new activity. Thus, despite all the limitations deriving from a lack of physical interaction, the rota applied to the assignment allowed to identify and stimulate those students who would tend to hide, often because of affective obstacles.

In recent research on affects, one of the most important issues has been the understanding of the interaction between affect and cognition, about how affect may influence cognition and, conversely, how cognition may impact affect. We hypothesised that the designed practice, which helped students activate shared cognitive processes, helped them overcome personal affective obstacles and vice versa. We referred to Goldin's idea of affective competencies based on that of meta-affects, i.e., the ability to monitor affect both through cognition and affect. Meta-affect refers to an *affect about affect, affect about and within cognition that may again be about affect* [18, 19].

In particular, we asked the following research questions:
RQ1: *How do cognitive roles within Thinking Groups (our model TG) affect emotional competencies in a mathematical problem-solving online activity?*
RQ2: *Does the use of online learning environments in a TG mathematical problem-solving activity foster conditions for developing emotional competencies?*

3 Design and Methodology

The Experimental Design. The experiment developed four problem-solving activities framed by integrating the DIST-M model and the TC model. According to the engagement model of Albano, Coppola, and Dello Iacono [10], our design foresaw working in groups and two levels of engagement in the problem solving process: the solving level and reflecting level. At the solving level, the Solver group was devoted to collectively solve the problem by acting according to the cognitive function to perform. At the reflecting level, an Onlooker group observed how the Solver group was working by reflecting on how a specific students acted with respect to both the mathematical problem and their role. A further level of reflection was added with respect to the previously cited engagement model of Albano et al. [10]. Indeed, we assumed a new goal in the task structure: the problem was split into three sub-problems, each of them aiming to fulfil specific sub-goals, going from employing mathematical concepts, facts, procedures, and reasoning to creating new mathematical knowledge. We envisaged as many Onlooker groups (O1, O2, O3) as there were sub-problems, so that each of them was mainly focused on one problem, namely group O1 on Problem 1, O2 on Problem 2, etc. Moreover, unlike in the Albano model, in order to foster the awareness of all the cognitive functions, the students changed roles with each new activity, also changing between Solver and Onlooker groups and permuting the Onlooker groups, and simultaneously, the problem or the typology of sub-problem to be focused on, according to a planned calendar.

According to the Liljedahl model [11], the groups were rethought as being inhabited by "thinking" students who collaborated for the development and creation of mathematical meanings by using vertical free boards and moving in very spacious classrooms or, eventually, as in our case, digital interactive boards.

Each student was required to draw up a personal logbook containing some guidelines to reflect on the role they assumed, both as Solver and as Onlooker. Furthermore, at the end of each learning activity, every Thinking Group was required to draw up a collective logbook, reporting the solution of the problem and the process made to reach it (detailing the experience, how the construction of the answers took place, and paying particular attention to the arguments they adduced when solving the three sub-problems).

Implementation of the Design. The experience, which was designed to have four different problem-solving activities, involved fifty mathematics undergraduate students attending a topology course [4] and working in three groups of 16–20, each of which was divided into four subgroups engaged at different levels. The Solver group S focused on collectively solving the problem, while the remaining three Onlooker groups, O1, O2, O3, were tasked with critically observing the Solver group's problem-solving process. Each student also acted according to fulfil of the cognitive roles that they were required to undertake as a Solver or Onlooker. The four planned activities CW_k (k = 1, 2, 3, 4) were implemented at intervals of 15 days from one another during the second semester of the 2020–21 academic year, while socially distancing due to the pandemic. All the participants, denoted by WG, were split into three groups, namely WG1, WG2, and WG3, which were each divided into four subgroups WSGi.1, WSGi.2, WSGi.3, and WSGi.4 (i = 1, 2, 3, 4). Each student was attributed a role-pair (subgroup role, individual role), one collective role, to solve or to reflect about the problem, and the other one individual, to perform or to observe a given role. Both individual and collective roles varied with the different CW_k tasks. The possible roles for a subgroup were S, O1, O2, and O3, while the individual roles corresponded to the cognitive ones, i.e., Boss, Blogger, Critical Mind, or Promoter. The set of individual roles was denoted with R_I and the set of subgroup roles with R_C to formalize this assignment with a function. For each CW_k activity, the following double-role product valued function was defined as:

$$r_k : WG \rightarrow R_C \times R_I$$
$$x \rightarrow (r_k^1(x), r_k^2(x))$$

where $r_k^1(x)$, $r_k^2(x)$ are the role of the subgroup and the individual role during the activity CW_k, respectively. For every $i \neq j$, we have ${r_i}^1(x) \neq {r_j}^1(x)$ and ${r_i}^2(x) \neq {r_j}^2(x)$, relating to the user changing roles in each round. As an example, if ${r_1}^1(x) = \mathit{O1}$, ${r_1}^2(x) = \mathit{Promoter}$, a student "*x*" was required to observe, without intervening, the work of the Solver group S concerning the first problem during the first CW_k activity and had to make observations about the member of the group who was acting as the Promoter (how would they behave in this role? Which path would they propose?). According to the double permutation of roles, in the second activity CW_2, a possible role-pair for the same student x could be ${r_2}^1(x) = \text{S}$ and ${r_2}^2(x) = \mathit{Critical\ mind}$. This means that during the second learning activity, s belonged to the Solver subgroup S and acted as a Critical Mind. All the criticisms and requests for clarification on the answers to the problems were made explicit. Only the Promoter had a communicative link with an expert (Guru) intervening to unlock a block if necessary. At the end, two documents (compiled in Google Docs) had to be produced, namely a collective one prepared by the Solver group S, which described in detail all the undertaken activities (procedure followed, motivations, paths followed and interrupted, etc.), and another individual one, in which the student reviewed their role.

A Sample of the Task. At the University level, the study of introductory topology can offer undergraduate mathematics students a suitable tool for the realization of significant problem-solving activities [4]. This may include ones in which examples are built for a profound acquisition of a concept, or ones in which conjectures are made and statements are proven, or counterexamples are produced to invalidate these. The Geometry III course taught during the second year of the Mathematics degree at the University of Salerno aims to introduce to undergraduate students fundamental concepts of general topology and to stimulate them to apply topological strategies. A substantial part of the course involves the study of topological spaces and their structure-preserving function, the construction of new topological spaces from old, and the topological properties that are invariant under continuous mappings, such as compactness and connection. The tasks are designed to promote the production of proofs linked to a learnt concept by passing through the construction of examples to deepen the concept [7]. For example, to determine the necessary or sufficient conditions for the properties expressed by that concept or some characterisation related to it. The tasks may deal with the notions of boundary, continuity, compactness, or connection. In every CW_k activity, the structure of the problem-solving task consisted of three problems, each aiming to fulfil a specific subgoal: the first two concerned the basic concepts introduced during the lectures and required the construction of examples of topological spaces or functions between them under given constraints (e.g., satisfying some required properties); the third one was less routine (for instance, students may have been asked to provide some characterisation related to the property that was being investigated). The following figures provide an insight into the kind of problems the students were asked to solve. The task in the second activity, CW_2, required the manipulation and conceptual understanding of the notion of the continuity of a function in a topological setting. In particular, in the first problem the students were asked to generate their own examples of continuous and non-continuous functions with respect to two invented topologies (on domain and codomain spaces) or to establish if a given function was continuous varying the topologies (see Fig. 1).

PROBLEM n.1

1.a Construct two topological spaces (S, τ), (S', τ') where S and S' are non-empty sets, τ and τ' are topologies on S and S', respectively, different from those studied during lessons (invent them !!), such that there exist a function $f_1 : (S, \tau) \to (S', \tau')$ which is continuous and a function $f_2 : (S, \tau) \to (S', \tau')$ which is not continuous.

1.b Consider the topological spaces you have defined in the previous problem (at point 1.a). Denote with τ_1 the topology τ, with τ_2 the topology τ', with τ_3, τ_4 the *trivial topology* on S and the *trivial topology* on S', respectively, and with τ_5, τ_6 the *discrete topology* on S and the *discrete topology* on S', respectively. Determine if $f : (S, \tau_i) \to (S', \tau_j)$ is continuous varying $i \in \{1, 3, 5\}$ and $j \in \{2, 4, 6\}$.

Fig. 1. The first problem

In the second problem, the students were asked to construct continuous functions satisfying some constraints (see Fig. 2).

PROBLEM n.2

Consider the topological spaces you have defined in the problem above (in point 1.a). Construct, if they exist, three different functions f_3, f_4, f_5 defined on S and with values in S', each distinct from f_1 f_2, satisfying the following conditions:

2.a $f_3 : (S, \tau_i) \to (S', \tau_j)$ is continuous in (S, τ_i), $\forall i \in \{1, 3, 5\}$ and $\forall j \in \{2, 4, 6\}$

2.b $f_4 : (S, \tau_i) \to (S', \tau_j)$ is not continuous in (S, τ_i), $\forall i \in \{1, 3, 5\}$ and $\forall j \in \{2, 4, 6\}$

2.c $\exists i \in \{1, 3, 5\}$ e $\exists j \in \{2, 4, 6\}$: $f_5 : (S, \tau_i) \to (S', \tau_j)$ is continuous and $\exists h \in \{1, 3, 5\}$ and $\exists k \in \{2, 4, 6\}$: $f_5 : (S, \tau_h) \to (S', \tau_k)$ is not continuous.

Fig. 2. The second problem

The third problem invited for the creation of a conjecture about the manipulated concept of continuity, for example some conditions, which were necessary or sufficient, or characterisations of the concept (see Fig. 3). This was a proof production task.

PROBLEM n.3

3.a Select two topological spaces (S, τ_i) and (S', τ_j) with $i \neq 5$ among those considered in problems 1 and 2 and investigate how this can be done: to define a continuous function $f : (S, \tau_i) \to (S', \tau_j)$. In other words, characterize, if possible, the continuous functions defined on (S, τ_i) and valued in (S', τ_j).

3.b Do the considerations made in the previous point or the statements you have reached also apply to the other topologies?
Consider at least two of the other topologies, (S, τ_k) on S and (S, τ_h) on S', with $h, k \notin \{i, j\}$, and establish if the results found for $f : (S, \tau_i) \to (S', \tau_j)$ still hold for $f : (S, \tau_k) \to (S', \tau_h)$.

Fig. 3. The third problem

Data Collection. All the data concerning the activity were stored digitally. The groups had at their disposal a digital environment consisting of various tools:

a) Microsoft Teams' platform to communicate online.
b) A collaborative Miro board [20], enabling collective brainstorming through the addition of post-its, import of images, drawing and connecting ideas, and exchanging comments through a chat, as shown in [11]. For example, the frame extracted from the Miro board (see Fig. 4) provides an insight into how a Solver group worked to solve the Problem1, reported on the right. The figure also shows the definitions of the basic concepts involved in the problem (topological structure, interior, closure, frontier etc.) on the post-it on the top, as well as some products coming from the students' attempts at inventing, when it existed, the required topology. In particular, the picture highlights that the investigation started from known examples and went

on manipulating them to construct the required topological space. Some results are reported in the table in Fig. 4.

c) Two Google Docs, one personal and the other one shared with the subgroup, to report the reflections concerning the individual roles played and the collective mathematical process applied by the subgroup, respectively. At the end of all the activities, the students were also required to answer a questionnaire related to the personal cognitive, metacognitive, and affective experiences they had.

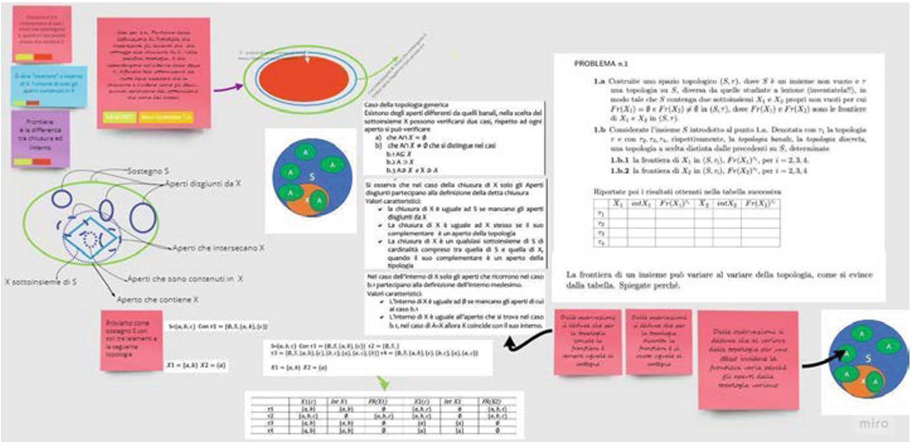

Fig. 4. Co-thinking about the problem on a Miro board

Analyses. Starting from the collection of data on the Miro board and in the documents, we focused our qualitative analysis on the students' emotional experiences during the problem-solving cooperative working on a Miro board. We identified the first affective outcomes, looking at the students' answers in:

– The questionnaire:

The students had an emotional experience during the activities. *What sensations did you experience during the activities? Have they changed over time? How? Beyond the exam, what did this experience leave you? Would you recommend a friend of yours to have a similar experience? Tell us why.*

In the activities, the students worked in an online Thinking Group using the digital interactive Miro board. *How did you find working and interacting with your peers through the online interactive Miro board? Did you only use it while you were working together with the members of your Thinking Group, or did you go to look at what you wrote on your own?*

Moreover, we highlighted the students' real time board benefits from some excerpts in:

– The personal logbook: *Describe how you played your role and what your contribution was. Do you think that the interventions related to your role were useful to achieve the goal? Why? Would you have done something differently? Why?*

4 Preliminary Findings

To shed light on the impact of cognitive roles within Thinking Groups on the emotional competencies of mathematics students, we analysed some logbooks and the questionnaires of 24 students from which we identified some emotional outcomes. The meta-affective potentialities of the experience were discovered.

4.1 Some Students' Affective Improvements During the Cooperative Working Experience

Our analyses appear to confirm that the structured activities helped students to overcome some affective obstacles. More precisely, in accordance with Goldin's hypothesis, the students told of having transformed fear into positive emotions and something pleasant during the experience, namely satisfaction, fun, and a reduction of shyness.

As an example, regarding the transformation of fear into satisfaction and from getting stuck and rigidity to *fluidity*, students St.10 and St.12 said the following:

St.10: I admit that I initially found the activities a bit difficult. Fortunately, however, I am not a person who gives up easily, so I rolled up my sleeves and tried my best to understand and apply all the concepts. In the end, I think I succeeded, and fear gave way to *satisfaction* and *a sense of fulfillment* for all the *work* that was done.

St.12: […] when I tried to solve the proposed problems, I found it difficult and tended *to get stuck* in some phases of the resolution. During the activities, this problem improved significantly, and I learnt to think about alternative solutions and to reflect thoroughly on the concepts studied going deep.

The following excerpt highlight the meta-affective potentialities of the experience. For example, the fear of making mistakes became pleasurable. The student recognised the fear of making mistakes as a necessary step for his own learning and this created a serene and more enjoyable working environment:

St.17: Before starting *I was very anxious* and I did not know what to expect. I did not know any of my fellow students enrolled in the course, and the idea of having this kind of experience with strangers scared me a bit. During the first activity, we were all very silent and we did not interact much; I think that under these circumstances, there is always the *fear of making mistakes* and being 'incompetent', which slowed me down a bit. Later, this all changed, when we became familiar with what awaited us; comparing on experience we realized that *it was necessary for us to make mistakes to get to the solution,* and this also allowed us to create a more serene environment, making the work more *enjoyable and fun.*

Finally, regarding the relations between self-confidence and judgment, St. 23 said:

St. 23: I was initially a little worried about the activities because I was afraid of not being able to do the required exercises and therefore not being able to help my group. However, these worries then faded as we started working together. In fact, even if I sometimes made mistakes, my fellow students always helped me understand my mistakes *without judging me.*

4.2 Some Students' Perceptions of the Affective Potentialities of the Miro Online Learning Board

These excerpts appear to confirm the immediate potentialities of the Miro board. It acted not only to provide a safe environment for students to collect everything that was needed (definitions, theorems…) to solve a problem, but also a tool representing a new way of making individual learning enjoyable and fun and helping shy students progress.

In particular, St.1 and St.11 highlighted MIro's perceived utility not only during the activities but also at the end of the experience:

St.1: […] thinking of doing something useful for those of us who might have some défaillance with the tools required to face the task, she wrote all the useful definitions in *a [Miro] frame*, such as boundary, interior, and closure [of a set]. This created *a sort of "safe-spot"***,** somewhere you could have everything you needed ready for use.

St.11: The student I observed, that is, the one who played the role of Blogger, played his role well, *collecting and tidying up the board*, highlighting some definitions and observations which were useful for carrying out the exercises through *the use of arrows* and schemes that made the key concepts clear. He took into consideration all the comments that were made.

Moreover, Miro is digital tool which supports metacognitive skills, since it enables a better organization of not only the students' collective work but also of the individual study. It serves as a tool to explore in different moments and to reflect on what was produced, as well as to monitor calmly the path to solve the problem.

St.13: Working with the online board made it *enjoyable to carry out the activity*, and the use of audio calls allowed us to collaborate better. Certainly, *having such a tool available meant that we could all see what was written in real time* and that we could better organize the thoughts themselves**.** *I used* the Miro board both when we worked in a group and *often alone, to reflect on what was produced.*

St.17: […] as a new experience, I would also define it *as fun, a new way of learning and studying* [..].

Students used different colored markers and post-it to write on Miro board and any color was associated with a cognitive role. St. 20 recognizes the importance to trace by colors the individual contributions to the solution of the problem with respect to the process path and to the role played:

St.20: […] I admit that it was the first time I worked on Miro, but it was quite exciting to check the various potentials and characteristics of the reference frames for each exercise.

In my group we used colored markers to write on Miro board, different colors associated directly with our personal contributions. *I went back several times* to what we had shared during the exercise to make our ideas more intelligible.

The digital board reduces face-to face contacts, but it seems to help to overcome some emotional obstacles. St. 26 perceives the digital board on one hand as a limiting tool in social sense, on the other hand as tool helping to manage shyness:

St. 26: [...] the use of a digital board does not allow for face-to-face communication but *helps the shy students significantly.*

5 Discussion and Conclusions

Recent research in mathematics education at the university level has prioritised not only academic learning but also the social and affective experiences of students. Particular attention has been paid to the secondary-tertiary transition [21], a delicate moment of personal growth and development in a student's life. The situation does not always improve in the stage following the secondary-tertiary transition, even for students enrolled in mathematics courses, especially when they are involved in problem-solving activities. We believe that problem-solving experiences are needed to support the students' developing competencies at different levels, and therefore, improve their maturity.

Our preliminary analysis appears to confirm that the structured cooperative problem-solving online experience, according to the TG model, combining the model of Albano et al. [10] with the TC model [11], fosters the development of processes oriented to achieve affective and meta-affective competencies [18], in addition to those already outlined in our research path [12]. The analysis of the students' responses to the feedback questionnaire generally showed that these activities had primarily favoured the social interactions that were lacking due to the pandemic. It further helped students overcome some obstacles such as shyness or a lack of self-confidence and allowed them to consolidate and acquire a deep understanding of the learnt concepts. This is a necessary step to allow the transition to the advanced mathematical thinking.

We argue that the students' engagement in such co-thinking activities and cooperative thinking experiences in structured Thinking Groups (TG) helped them to improve their self-thinking, as it allowed the students to transfer personified cognitive roles from the Thinking Group to their individual minds, thus passing from a structured learning approach to a self-structured one, by transposing, or in other words, projecting this collective experience into their self-regulated study. This has generated research questions for some possible future developments. We hypothesise that this practice could also allow students to implement self-strategies oriented at achieving well-being goals and fostering performance and learning goals in their self-regulated learning [22–24].

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Nussbaum's Lesson on Public Emotions: A Sociological Reading in an On-Line Academic Environment

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Abstract. The numerous virtual learning environments experienced during the pandemic in the academic field highlight the need for a complex pragmatic analytical approach that considers the centrality of the pedagogical relationship and its personal and social consequences. When faced with societies threatened by permanent global risks, the possibility of going back to a central and classical theme like the formation of the good citizen appears as paramount. The centrality of the relational and personal approach and the importance of the political dimension of education evoke the relevance attributed by M. Nussbaum to public emotions in the formation of a democratic society. Why could it be important today to think of higher education in the light of Nussbaum's approach to public emotions? And how is it possible to arouse public emotions, furthermore in a virtual educational environment for example in a course at an online university?

The contribution is divided into two sections. The first is dedicated to understanding the sociological relevance that Nussbaum's approach to public emotions could have in the academic field. The second deals with the analysis of the forms that public emotions could take during an experimental teaching practice in a course delivered in blended mode in an online university.

Keywords: Public Emotions · Human Participation · Blended Teaching Practices

1 Introduction

The recent pandemic and the consequent sudden transformation of numerous university courses into online courses has brought out a new organization of academic work but also new educational needs [1]. The latter appear consistent not only with the digital skills of the teachers but with skills that can be defined as transversal, such as relational skills and those related to the ability to provoke a historical-critical thought in students. As intuited by the European legislator[1], digital skills appear increasingly grafted into key

[1] The reference is to the Recommendation of the European Parliament and of the Council of 18/12/2006. The European key competences (established in the European framework for life-long learning) have been transposed by the Italian legislator with ministerial decree no. 139 of 22/08/2007 and translated into the key competences of citizenship.

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competences of citizenship [2, 3]. From a sociological point of view, in the academic field, the analysis regarding the key competences of citizenship re-proposes the centrality of the question of the formation of the good citizen. The theme seems particularly pertinent with respect to the crises of liberal democracies and the emergencies, even in Western societies, posed by various nationalisms and populisms [4, 5], but also with respect to a higher education increasingly oriented to labour markets [6].

In contemporary risk societies, how can wide-ranging educational needs coexist with more instrumental needs oriented above all to the employability of the new generations? And above all, how could university education help shape the form of democratic political systems?

Pragmatic-cognitive sociology enhances the formative meaning of the educational experience [7]; according to this tradition of research, the educational situation is a significant situation that modifies the vital worlds of individuals and with them the ways in which social actors perceive themselves and others in the world [8]. This tradition gives a specific emphasis to emotions, emphasizing above all their social genesis and their cohesive potential within societies [9, 10]. Emotions and, particularly, public ones, were placed by M. Nussbaum at the center of the formation of a more equitable society [11]. Integrating Nussbaum's proposal into a sociological-pragmatic framework [12], the contribution proposes a reflection on teaching practices that in an online university could stimulate public emotions. The study is divided into two phases. The first is reserved to explore the sociological-pragmatic relevance of Nussbaum's approach to public emotions. The second to the analysis of an experimental teaching practice: the intensive semi-face-to-face week. The methodology used for the empirical analysis is that of action research, in which the researcher has the dual role of researcher and teacher. In particular, the first phase of the research (reconstructed in paragraph 2) is aimed at understanding the social nature of public emotions and, following Nussbaum's interpretation, the most suitable teaching strategies to promote them. The second phase (presented in paragraph 3) is instead aimed at analyzing the participatory logics that arise both during the online phase and during the phase in the presence of the teaching experience. In particular, the emphasis is placed on the mechanism of transformation of social participations into human participations and on the functions that artistic texts and digital tools perform in this process.

2 The Sociological Relevance of Nussbaum's Approach to Public Emotions

Moving away from a substantialist conception of political emotions, which is present for example in Comte, and deepening a pragmatic conception, Nussbaum investigates public emotions considering them a form of life necessary, rather than to maintain the democratic order, to innovate it. The fulcrum of her approach is on the one hand the need to make people participate, to make them feel protagonists of their political community, on the other the awareness that the *chances* of participation in public life are different for different citizens. Political emotions, in Nussbaum's conception, are social sentiments [13] that promote in the members of a political community the desire-work to perceive their uniqueness not in opposition but in harmony, in agreement with other political communities, in a broader effort to discover and value the political community as a human community.

This conception appears sociologically relevant in relation to university education at least for the following three reasons:

a) for the inclusion of public emotions in a theory of social participation.
b) for the historical importance of social participation.
c) for having posed the question of the cognitive and normative conditions that allow the transformation of social participation into human participation.

2.1 Public Emotions and Social Participation

According to Nussbaum, social participation, which is considered key to the political morphogenesis of societies, is learned and in this process public emotions play a central role. The thesis is sociologically relevant above all because it inscribes the political forms of society, political systems, in broader processes of communitarisation and association, with respect to which political systems appear almost epiphenomenal. The social framework that the philosopher proposes of political systems is not mechanical, it is already found in relational social phenomenologies, fueled by public emotions that appear particularly interesting for their ambivalence. Indeed, they can both promote the democratic configurations of contemporary societies and contribute to deforming and disfiguring them.

Applying such a perspective to the academic context seems particularly interesting, first for the activist imprint that it conveys, social participation is in fact understood not only as the end of the educational process but also as a privileged way to achieve it through the personal involvement of teachers and students. Secondly, also for the specificity of the process of individualization that university education proposes. In fact, in the process of professionalization that the academic education specifically outlines the social recognition received by the students and, to use Dewey's vocabulary, its *direction* becomes fundamental for future processes of social morphogenesis [14].

The originality of the social participation proposed by Nussbaum as a central element of the educational process consists in the function that emotions play in its genesis. Emotions are not states of mind separated from actions, they are life forms that arise from social interactions, they are genetically relational and susceptible to assume different meanings as social situations change. The social formation of emotions makes it possible to place the aims of educational processes within the educational experience, in order to understand them and to adjust them according to the modification of the experience itself. Moreover, the genesis and social development of emotions confer an analytical primacy to the actors involved in the experience and to their interpersonal relationships, highlighting the indefinite and, potentially, open, and modifiable character of the educational experience. But that's not all. The social nature of emotions appears particularly interesting in relation to the educational experience above all for its pragmatic character. In fact, according to Nussbaum, emotions are *cognitive frames* that make the understanding, the intelligibility of the world possible and at the same time allow to participate in it, to find in it one's own place with respect to others. In this sense, emotions are not inner reactions to outside stimuli, but they are ways of thinking and being in relation to one's self and the others, ways through which it is possible to access knowledge of oneself and of the world, preferential tools of knowledge and conduct [15]. As Cerulo points out [16], the value of emotions for Nussbaum is *cognitive and evaluative*, it could be defined morphogenetic since they contribute to the genesis of society, to its making through the processes of individualization and communitarisation.

The morphogenetic character of emotions, particularly of public ones, not only gives new centrality to the educational experience but helps to redefine it as a predominantly emotional experience, during which one can discover one's professional value and understand one's professional participation in society.

2.2 Historicity of Social Participation

The historical dimension of social participation is understandable in the light of the attention that Nussbaum, following Sen, dedicates to social inequalities and, more generally, to the theme of social justice [17, 18]. The fact that the *chances* of social participation can be very heterogeneous for different individuals and in relation to the social contexts in which they live is a fact that conditions the educational experience, its forms, and its results. Grafting social participation into the material living conditions of individuals means understanding the historical-social dimension of democracies, understanding that individual freedoms of participation in the political regulation of society can be very different depending on both the material resources of individuals and their cognitive resources. However, redefining the theme of social participation in a historical sense has a specific pragmatic meaning in Nussbaum, it means considering the educational experience central to its transformative potential. In this perspective, the educational experience and, particularly, the university experience, not only contributes, as underlined among others by Bourdieu [19], to re-producing the starting social positions of individuals but is configured as an instrument of possible social mobility. In the analysis of this process, even with respect to Rawls's theory of social justice, it is interesting that the basis of social mobility is not exclusively conceived in relation to the material resources available to individuals. The problem is not only linked to the redistribution of income but is more complex, it is linked to *the enabling function of the educational context*, and to the possibility of the latter to arouse in individuals not only desire to learn, but also effective and personal forms of social participation, and finally, non-instrumental social participation.

These assumptions, if related to the function that Nussbaum attributes to public emotions and if analyzed in relation to an online academic context, underline the enabling function of the virtual learning environment [20, 21]. The latter, far from being unrelated to it, it is an integral part of the educational experience, as it is configured as a space that both makes the educational relationships possible and gives them shape, particularly, to their emotional dimension. Above all, since it must bring closer together, it must not therefore be conceived as an invisible wall, which is nonetheless present and, frequently fed by the scarce digital skills of teachers and students, instead should be conceived as a co-participatory space, an environment that facilitates communication, discovery, and learning. A proximal community space [22], i.e., a multi-agent and multimedia space aimed above all at enabling and inspiring in students, trust in their professional abilities and desire for social participation.

2.3 The Transformation of Social Participation into Human Participation

Nussbaum's proposal does not limit itself to indicating a direction for the development of social participation, but rather it goes so far as to indicate what might appear to be *a democratic teaching methodology*. Tracing what the philosopher herself defines a moderate essentialism, among the public emotions she has no hesitation in pointing out some that perform the function of transforming social participation into human participation better than others. Among these, respect, and compassion on the one hand and disgust and shame on the other play an extraordinary role.

But what seems didactically more interesting is the way in which these emotions are stimulated. Regarding this aspect, art but also political communication constitute treasure troves. Fundamental in the didactic use of "texts", however, is the contextualization of them that the teacher is able to create during the educational experience. In the process of contextualization, the teacher performs a function like that of the linguistic translator, as they must be able not only to propose the text to the students but also be able to offer them the cognitive and normative tools to understand and evaluate its universality. They must be able to both make students identify with the vital experience that the text represents and be able to make them distance themselves from it, allowing them to question the idea of the human condition that the text presupposes and proposes.

As Nussbaum suggests in the book *Political Emotions: Why Love Matters for Justice*, if it is true that public emotions appear culturally conditioned by political, religious and, more generally, by heterogeneous cultural systems, it is not equally true that all human values and behaviors are equivalent. Nussbaum concedes nothing to relativism and fights it on the level of method rather than on the level of war between multiple and different values. The works of art and the political discourses that she proposes for analysis are not in fact interesting for the values that they individually transmit and that, precisely because of the cultural differences of the public, can be interpreted differently, but rather for the idea of relationship and human experience that they indicate. It is a specifically human way of being that Nussbaum seeks in the proposed works, it is the possibility of discovering in the Other not only always an end but the fineness of human life. Nussbaum's goal is to let the reader enter a dialogue with the Other in search of the common human condition, of the limits that characterize it and of the responsibilities for its development. It is this agenda which transforms social participation into human participation.

With these elements Nussbaum proposes what could be defined a *practical democratic teaching* and highlights some of its milestones: 1) human participation as a distinctive element of democratic societies and 2) practices of human co-participation learned and experienced during university courses rather than through theoretical models. These practices are based on sharing paths of discovery of one's own humanity, of what has been defined by Martuccelli as a *horizontal transcendence*, the possibility of perceiving the historicity of one's own beliefs and values through the knowledge of those of others [23]. In such a relational process the possibility of discovering in the Other not their personal interest or their power, but rather a common human condition and the beauty that characterizes it, similar needs and possibilities of social recognition and social participation becomes the key to the search for the contribution that each one, with one's own professional conduct, can offer to the constitution of a more just society.

3 An Experimental Teaching Practice: The Semi-face-To-Face Intensive week

The understanding of the sociological relevance of Nussbaum's approach invites us to explore its applicability in an experimental teaching practice carried out in an online academic context.

How is it possible to stimulate public emotions such as those proposed by Nussbaum in university students, attending an online university?

We tried to answer this question through empirical research conducted in an experimental teaching practice, during the semi-face-to-face intensive weeks carried out during the academic years 2019–2020 and 2020–2021 in the Urban Sociology and Sociology of Economic Processes courses within of Communication Sciences course of study at eCampus Telematic University.

3.1 Research Design

The research, of an exploratory type, aimed to understand how in a university environment, organized in a blended mode, it is possible to provoke and record public emotions, such as respect, compassion, disgust or shame and through which teaching strategies it may be possible.

The research field was constituted by a teaching activity articulated into five days, of which four of online teaching and one of face-to-face teaching.

Consistent with the pragmatic framework, the educational experience has been considered the fundamental moment of the research. Starting from the idea that public emotions are shared social languages suitable to connect the university classroom with society in a broader sense, in order to project on a larger scale what has been experienced at a local community level, it was decided to analyze the educational experience emerging from teaching practice as a *community experience* potentially generative of public emotions. Following this approach, the educational experience has been analyzed in its constitutive participatory logics in two distinct moments, that of online attendance and that of face-to-face attendance. In both these moments the constitutive participatory logics of the community experience were investigated, seeking in them the genesis and expressions of public emotions. In the analysis of participatory logics, the goal was to understand not so much the birth of community feelings of solidarity between students and teachers but rather the genesis of social participation in the community fueled by beliefs and feelings of sharing the same human condition.

The research was conducted through the technique of research-action, the data collected through the teacher's notes have been later processed with a statistical study. The research-action is a qualitative technique of social research owing to ethnographic techniques, recently spread also in the field of the sociology of education [24–26]. In it the teacher played the dual role of teacher and researcher. Accordingly, the researcher tried to apply Nussbaum's approach following the methodological and pragmatic path indicated by her: in the class in which the researcher teaches, they study the emotional reactions of students to some didactic strategies. In particular, they study the students' reactions to the following strategies:

a) the personal involvement in the course of students and teachers through frequent requests for personal interventions coming from the teacher and addressed to the students;
b) the sharing of digital skills among participants in the use of virtual learning environment;
c) the integration of artistic texts and political speeches among the teaching materials;
d) the encouragement to link the contents learned to previous personal experiences;
e) the creation of work-project groups.

From a more strictly methodological point of view, the teacher, in addition to conducting the lesson, during the lesson or immediately after, takes notes in the research diary about the behavior of the students distinguishing:

a) the students' contributions during the lesson (noting the frequency of individual contributions, the themes of contributions, the language used, and the emotions expressed).
b) The participatory modalities of the students in the lesson (noting the responses to submissions to be carried out cooperatively, the attention towards the teacher and towards colleagues, the creativity in the use of the virtual and physical learning environment, and the emotions expressed).

In the same diary, the teacher noted, both during and immediately after the lessons, its own emotional involvement in the lessons, noting in particular:

a) the desire to finish the lesson or, on the contrary, to prolong its duration;
b) the satisfaction for its conduct, the discomfort or annoyance felt during the lesson.

The students' reactions to the various teaching strategies proposed by the teacher and the reactions of the teacher himself, after being noted in a diary, have been analyzed through a statistical study. In particular, in order to highlight the distinctive features of the reactions of the students involved in the teaching strategies, two distinct samples were set up: a sample of students involved in the research and a control one (both samples were made up of 40 students).

After forming the samples, according to the statistical study conducted by Kanetaki *et al.* [27], the correspondence between the students' reactions and the public emotions that have emerged during the teaching practice in the sample involved was analyzed.

3.2 First Evidence: Some Emergent Effects

Conducted with 40 students distributed in four distinct teaching cycles, firstly the research highlights some emerging effects recurrent in all didactic cycles analyzed. According to Boudon's definition [28], the emergent effects are consequences that emerge in an unexpected way and almost spontaneously from the field of research.

The first effect is the positive correlation between students' participatory logics and public emotions.

The second is the alliance between teacher and the virtual learning environment on the formation of an emotional learning experience.

And the last effect concerns the complementarity between the face-to-face and online teaching experience in arousing public emotions.

Regarding the relationship between students' participatory logics and public emotions, in each of the four didactic cycles considered, it is possible to note that a percentage between 60 and 78% of students expresses mutual attention and shows understanding for issues of social justice, improving their personal participation in the course with contributions more collaborative and creative (Table 1).

Table 1. Students' percentage showing mutual attention, understanding related to problems of social justice and collaborative participations in teaching activities.

Students' percentage that show mutual attention, understanding related to problems of social justice, collaborative participation			
	Mutual Attention	Understanding issues of social justice	Collaborative participation
I cycle	65%	60%	70%
II cycle	68%	62%	74%
III cycle	64%	63%	78%
IV cycle	62%	65%	76%

The Fig. 1 shows how, in the sample of students involved in the teaching practice, as participation and involvement in teaching activity grows, mutual attention emerges among students and also understanding of problems related to social justice.

In relation to the second result, the alliance between teacher, digital tools and public emotions, especially in the online context, appears clearly. In the cases in which it is easier to search and share teaching materials and in which it is easier to integrate artistic texts into the course, a percentage close to 85% of those attending the course express public emotions with a universal vocation as human respect and indignation for reprehensible human behaviors.

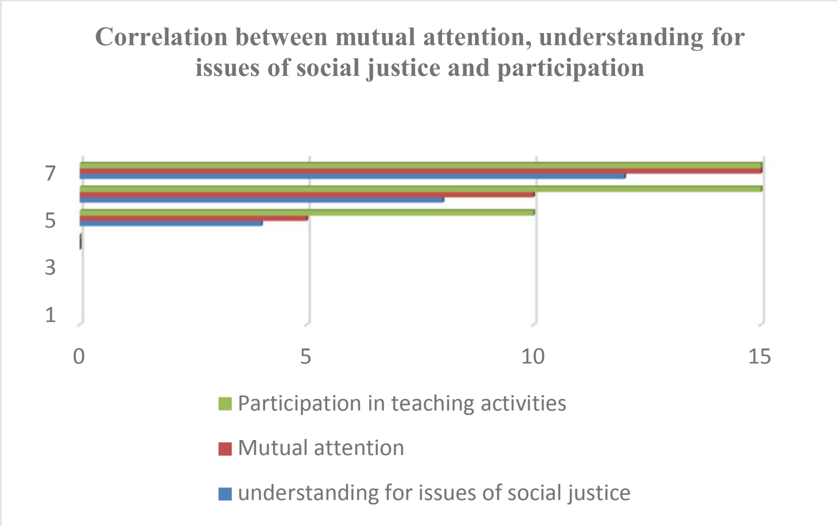

Fig. 1. Correlation between mutual attention, understanding related to social justice and participation in teaching activities.

Finally, concerning the complementarity between the on-line and face-to-face phases, the search in almost all the data taken into consideration (contributions and participatory logics of the students and emotional involvement of the teacher) does not reveal significant differences. However, the research helps to clarify the centrality of the emotional experience in both phases and the authentication function of the emotional experience played by the in-person phase.

3.3 From the Emergent Effects to the First Analysis

3.3.1 The Personal and Participatory Style of Contributions

With reference to the relationship between the participants' contributions and the public emotions, the variables that were considered were the frequency and style of the contributions, the latter re-constructed through a discursive analysis aimed at understanding the recurrence of the narration of personal experiences, the willingness to listen to the experiences of others, the interest shown towards the contributions of others and the extent of replies to the contributions of others.

Over the course of the entire semi-face-to-face intensive week and on all cycles, the analysis of these variables shows the progressive construction of the common emotional world with, however, its most intense phase during the first and second day of the week.

In these two days, the frequency and participatory style of the contributions, detected between 70% and 75% of contributions, appears to be created by the involvement of the teacher in the creation of a historical-personal relationship with all the students. The work on the formation of a historical-personal relationship constitutes a transformation in an intersubjective and personal sense of the educational experience, it redefines the educational situation by inserting it in a historical perspective that transcends it. This work is carried out through a fundamental demand for social participation addressed to all students and having as its field of exploration the problematization stimulated by the topics of the course and through the availability of the teacher first, to engage emotionally in the educational relationship. The emotional commitment of the teacher translates into the willingness to narrate episodes of its own training and is realized in the desire to know their students not by discovering everything that the latter do not know but trying to understand everything that can be discovered and learned together.

In the online context, the possibility of such a job appears very conditioned by the possibilities offered by digital tools, first by the quality of the connection and hardware tools available and by participants' skills in their use. The good quality of the audio, the quality of the visual images are all fundamental elements that facilitate the establishment of a personal relationship between teacher and students and between the various students. The quality of the tools supports the teacher in the work of interpretation-connection, which they carry out especially in the first days. In this phase, the possibility of observing the different work environments of the various participants in the course offers elements of mutual knowledge, is configured as a possibility to look beyond the personal worlds of the participants and contributes to that role-setting work in which the teacher is engaged. In fact, within the professional roles interpreted, they must be able to reveal and show to students the participation of all to such a human condition and the effort of all to make it more intelligible.

3.3.2 The Creative and Collaborative Learning

The participation of students in the educational activities proposed during the week, in 85% of the cases analyzed, revealed what can be defined as a creative-collaborative learning based on the support offered by digital tools and fertile for the birth of public emotions. The students, in all four cycles analyzed, on the third and fourth online day of the week, responded positively to the request to organize themselves in groups and design projects related to the topics covered in the course. In the organization and management of group work, they showed a spirit of collaboration, mutual listening, respect for speaking turns, mutual requests for contribution, spirit of inclusion, respect and enthusiasm for the most original solutions found by some of the participants. This phase is not exclusively in continuity with the previous one, it is, already partly, configured as an implementation of the previous one. During this phase, in fact, two intertwined explorations continue, on the one hand that of mutual interpersonal knowledge, on the other that aimed at the problematization of the contents of the course. In this double exploration, the intuitiveness in the use of digital tools, the possibility of personalizing one's didactic participation with the creation of personal learning objects, the possibility of promoting collaborative didactic action, and above all, the synesthetic experience that they can promote are all elements that facilitate the establishment of a common emotional world. This latter is based above all on the discovery and recognition by all participants involved in the educational experience of the value of each participant as a human person. In this phase the role assumed by the "artistic" texts used in the previous days is particularly interesting, they are not taken up mechanically but encourage the search for similar texts also by other authors, they are sought after for their expressive, aggregative, and aesthetic-political capacity. During the project phase, the artistic texts seem to facilitate the formation of emotions with a universal vocation, they allow not so much the identification of some values around which the project can revolve (e.g. sustainability, inclusion, efficiency, etc.) but rather an effort of idealization aimed to the community constitution. Accordingly, they play an expressive and aggregative function, but also an aesthetic-political function, they explore the agreement of preferences and their ability to transcend individualities in search of a human intersubjectivity.

In the online project phase, the customizability of the virtual learning environment, the ease of its use, the possibility that it hosts and makes usable different multi-media tools, that it is for example organizable in distinct virtual rooms, which allows one to work simultaneously on common texts and synchronously, without ever losing the images of those who are operating, these are all elements that promote a creative and collaborative learning [21, 29–31].

3.3.3 The Authentication of the Educational Experience During the Face-To-Face Phase

The face-to-face presentations of the work projects, during the last day of the semi-face-to-face intensive week, in all the projects presented and in all the analyzed cycles, reveal the presence of what Nussbaum defines as public emotions.

Within the courses of Sociology of Economic Processes and Urban Sociology, in the presentations of the various projects, emotions took the form of the valorization of economic behaviors and practices based on respect for the variety of different economic cultures but at the same time on the clear identification of those behaviors and practices that most promote social justice and human dignity.

What generated this result and what happened during the face-to-face phase of the intensive week?

The result, i.e., the formation of public emotions, does not appear to be a result attributable exclusively to the face-to-face phase of the teaching experience, on the contrary it emerges progressively and is prepared by the online phase. The face-to-face phase, however, helps to adjust the result and, probably, to make the whole process more intelligible. During the face-to-face phase, one perceives not only the fullness of sociality that nourishes the educational experience [32, 33] but also the traits that unite it to the online phase and those that distinguish it. Among those that unite the two phases it is now evident that there is a *need for human proximity*; the educational experience, both online and face-to-face, is an experience in which to cross the space existing between individuals and reduce their mutual distance. From this point of view, the educational experience is configured as an emotional experience in the measure in which it allows participants (teachers and students) to experience their common human condition. This experimentation is a common research path, it consists in getting closer to the other, in sharing the limits of the historic human condition and, at the same time, in moving away from it to discovering the universal specificities of the human condition. This research path is based on the personal value that the educational experience creates and circulates and on the possibility of sharing human participation in the formation of society. The relationship between personal value and human participation is particularly interesting, it seems to be the key that allows to transform social participation into human participation, into a personal participation in society based on the universal human dignity of all people and on its promotion [34]. Among the characteristics that instead differentiate the online teaching experience from the face-to-face one there is the real character of space and its concrete possibility of being inhabited. In the face-to-face experience, in some ways one wants to authenticate the online experience, prove that it is real. This attempt is configured as a historical experience since it makes the spaces "true" and "real" and, consequently, also the distances and, therefore, the transformative possibilities conveyed by the online teaching experience more limited. It is not true that face-to-face everything is simpler, it is true instead that this experience is more direct, not mediated by digital tools. The direct nature of the experience allows for a more complete understanding of the situation in its actual possibilities of transformation, for example it allows for an understanding more based on the diversity and uniqueness of the participants. Consequently, in the face-to-face phase, the process of communitarisation and idealization, fully started during the online phase, reveal their difficulties, as if the actual chances for example in students' performances become more evident. The face-to-face phase is therefore configured as the political moment par excellence, the one in which agreements and idealizations are adjusted and, in some ways, are downsized. However, this adjustment is necessary to make the projects and public emotions present in them more achievable. Public emotions, particularly in the face-to-face phase, seem to recall Natalia Ginzburg's *small virtues*, that is, not small values, but experienced public values, applied in one's own daily life, which have become daily behaviors [35].

3.3.4 The Formation of a Common Emotional World with a Universal Vocation

What justifies the positive correlation between a high level of personal participation in the course and the public emotions expressed by the participants?

The reconstruction of the participation logics of the people involved in the semi-presential intensive week is useful for describing what appears to be a common emotional world suitable for arousing public emotions with a universal vocation.

According to Schutz [36], a common emotional world in learning environment is constituted by a communicative situation in which not only the contents of the course are transferred and circulated, but mutual expectations of knowledge are explored. In this situation the contents of the course are constantly referred to the life experiences of individuals and immersed in the interpersonal relationships. The common emotional world with a universal vocation arises not only from the sharing of life experiences but from their problematization, from the discovery of a common human condition that precedes the social roles and conditions of individuals. The participatory logics if supported by the personal emotional involvement of the teacher, by their interest in the knowledge of individual students, by the enhancement of the contribution that each student can make to the knowledge of a given theme, by their courage in showing the disciplinary and personal limits of their own knowledge with respect to the breadth of the topics covered, creates a favourable substrate for the birth of what could be defined as *public emotions with a universal vocation.* What emerges is a common emotional world full of the narration of previous personal experiences and studded with what Jedlowski calls memories of the future [37]. The memories of the future are future expectations built from the sharing of previous life experiences, on the one hand by the recognition of the limits of one's own experiences, on the other by the trust in the possibility of being able to participate in the formation of a more human world.

4 Conclusions

Nussbaum's thinking on the relationship between public emotions and democracy invites us to investigate the ways in which it is possible to stimulate public emotions in students during an online university course. The inscription of Nussbaum's thought in a sociological-pragmatic framework helps to highlight the social formation of public emotions and the pragmatic character of the educational experience. Starting from such an approach, with the aim of understanding what happens during an online university educational experience and how the latter can constitute a favorable ground for the birth of public emotions, an empirical research has been carried out. This research had as field of investigation an experimental teaching practice: an intensive semi-face-to-face week realized in four cycles during the years 2019–2020 and 2020–2021 in the Sociology of Economic Processes and Urban Sociology courses at the eCampus Telematic University.

Carried out following the action-research model, the research involved forty students and a teacher and studied the emotions that arose during the intensive week, analyzing the style of participation of the contributions in the educational activities undertaken and the emotions expressed during their realization.

The data collected was analyzed through a statistical study which showed the positive correlation between student participation in educational activities and the emergence of public emotions such as mutual attention among participants and understanding of problems related to social justice.

The results of the research show the constitution of a participatory style and collaborative and creative forms of learning favorable to the birth of public emotions. These results appear interesting for the logics of social participation that they reveal. The logics appear to be fueled by the creation of a historical-personal relationship between teacher and students functional to the constitution of a world in which all participants unlearn to think of personal education in utilitarian terms and discover instead the common human condition and the possibility of each one to participate in the construction of a more human world. In the activation and sharing of such logics, the role of the teacher, his involvement in the educational experience seems the hidden term of the equation. If the teacher's engagement is not immediately evident, his tools appear clearly. The function of artistic texts and digital tools seems fundamental. Both these instruments have an aesthetic-political function, they can help to create not identity participations but universal co-participations in human society, they can make everyone discover their own professional value with respect to the development of human society and its historical problems.

The research also shows the complementarity between the on-line and face-to-face teaching experience and some distinctive features. During the face-to-face phase, the formation of the common emotional world continues, based on mutual recognition, on learning an attentional way of relating to each other, and on sharing emotions preformed during the online phase. However, during the face-to-face phase the truthfulness and authenticity of what has been lived and already built in common is experienced, as if mutual judgments and the pre-formed common world were, during the face-to-face phase, put to the test, and if necessary adjusted in their possibilities of finding a concrete realization. The face-to-face phase is therefore configured as an adjustment phase of the emotions already experienced but at the same time also as a phase of concrete planning, as if the authentication of the experience lived online gave rise to a more real historicization and the consequent possibility of concretely prefiguring the professional participation of each one to society.

The intensive semi-face-to-face week analyzed is only an expression of an experimental teaching practice, repeated cyclically four times, during the years 2019–2020 and 2020–2021. Within the limits of the exploratory research presented, however, the following relevant questions emerge:

can public emotions be thought as educational paths rather than as substantial values? In other words, is it possible for the educational experience itself to be configured as the place in which to learn logics of social participation consistent with the promotion of the equal dignity of all men? And if so, what kind of involvement in the educational relationship would be necessary on the part of the teacher and what function do artistic texts and digital tools play in the construction of a common emotional world suitable for the constitution of public emotions of the type imagined by Nussbaum?

Far from answering such relevant questions, the research presented limits itself to underlining their relevance for designing future research projects.

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The Digitization of Onboarding Processes of New Joiners Aimed at Enhancing Soft and Hard Skills

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Abstract. Through the analysis of the process of insertion and training of young graduates in a financial business context, the study highlights the unexpected effects of professional training based on technological tools. The contribution illustrates how the digital skills of recent graduates within a complex organization can respond to training needs not only related to technical skills but also to transversal skills suitable for enabling a path for the integration of young people based on creative skills and collaborative attitudes.

Keywords: e-learning · new hires · onboarding · socialization

1 Introduction

The entrenchment of the COVID-19 pandemic in the daily lives of billions of people around the world has had a profound impact on the way in which activities involving human-machine interactions are carried out, requiring rethinking and careful preliminary planning of individual processes.

Studies have shown that an effective online transition requires the integration of synchronous and asynchronous tools into a seamless online distribution, overcoming barriers to access to technology, improving online skills for students and teachers, the optimal management of privacy and confidentiality policies. In the context of these studies, some answers emerged for a framework of best practices of online education: 1) technological support for teachers and students, in addition to the careful development of online teaching materials 2) design of blended learning paths, which combine the online experience to that of physical spaces, in preparation for the post-covid period 3) offering specific training on educational technologies and their effective use, for both teachers and students 4) enabling a strong sense of connection among students through their active participation in groups / communities. The real challenge, cross to these issues, however, remains that of using the technological and innovative potential of digitalisation in order to always and in any case enhance people.

The number of people choosing to quit and work in new organizations is increasing. (Bauer and Erdogan, 2011) and 90% of new hires decide whether to stay or leave within the first six months (Johnson and Senges, 2010). Also, newcomers who enter a

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new organization have about three months to prove they are members (Bauer, 2010). The process by which "the new employees move from being an outsider to the organization to becoming an insider of the organization "is called onboarding (Bauer and Erdogan, 2011). A company with an intentional and "thought" onboarding process, experiences greater retention, greater job satisfaction and reduced time to productivity. However, despite its importance, only a fifth of companies involve newcomers in a proactive and organized onboarding plan (Bauer, 2010). The consequences of insufficient or non-existent onboarding are expensive rotation of the personnel, lower performance levels and less commitment (Bauer, 2010). Furthermore, the research has demonstrated the attitudes that a newcomer develops in the first weeks of work remain relatively stable (Johnson and Senges, 2010).

An onboarding process usually takes place in a limited amount of time, starting from when the job offer is presented and continues for up to twelve months (Chillakuri, 2020).

However, because onboarding deals with the efforts made by the organization, the period of time can vary a lot. The best performing companies tend to consider onboarding as a longer process than the industry average, especially up to six months versus a month (Aberdeen Group, 2006).

At the heart of the onboarding literature are the expected outcomes of successfully pursued onboarding processes. Although the literature is not entirely consistent, it distinguishes between short-term and long-term outcomes. Short-term results are more related to the newcomer and affirm themselves as self-efficacy, clarity of role, social integration and knowledge of culture (Bauer, 2010; Bauer et al., 2007). How long concerns the most sought-after long-term outcomes, studies have found multiple effects of a successful integration where the most important are greater loyalty, job satisfaction and performance (Bauer and Erdogan, 2011; Bauer et al., 2007; Bauer, 2010; Snell, 2006), shown in Fig. 1.

Fig. 1. Illustration of onboarding and expected results

The performance level of a newcomer is usually expressed as the time it takes for productivity, which means time necessary for a newcomer to become fully productive, illustrated in Fig. 2, inspired by Snell (2006).

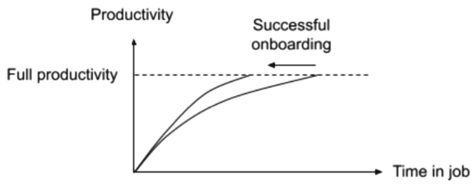

Fig. 2. Time for Productivity

Furthermore, Bauer (2010) points out that “the faster the new hires they will feel welcome and prepared for their job, the faster they will be able to contribute successfully to the company’s mission”.

Bauer (2010) distinguishes informal and formal onboarding, describing the informal as a newcomer learning the job without a detailed plan, also called an approach "sink or swim". Such an approach implies that a newcomer must learn to behave independently (Van Maanen and Schein, 1979) without the help of the organization, leaving the success of socialization to the efforts of the individual (Cambridge Dictionary, 2022). On the other part, formal onboarding is described as “a written set of policies and procedures coordinates that help an employee adapt to his new job in terms of both tasks than socialization.” (Bauer, 2010). Continuously, Bauer (2010) argues that programs “best-in-class” onboarding systems use a more formal approach. The next subsection will introduce three theoretical models that a practitioner can use to formalize the process onboarding.

2 Research Objectives and Hypotheses

This study aims to shed light on a previously unexplored niche in the relevant literature regarding the challenges that companies face while implementing a structured and repeatable onboarding program, while the company itself is changing as a result of the thousands of hires it will have to finalize in the next short period.

Driven also by the new behaviors induced by the covid 19 pandemic, increasingly oriented to the extreme use of technology both in production processes and on those of Human Resource Management, the study also wants to understand how technology is able to enhance the work contribution of people in the processes of onboarding and eLearning.

The mail question is: “How have educational technologies helped in the transition?”.

A useful framework that encompasses the knowledge and skills demands of contemporary educators is the Technological Pedagogical Content Knowledge Model (TPACK) (Archambault & Barnett, 2010; Cox & Graham, 2009; Jang & Tsai, 2013). Figure 3 shows the triad of TPACK’s interconnected didactic knowledge: pedagogy, content and technology.

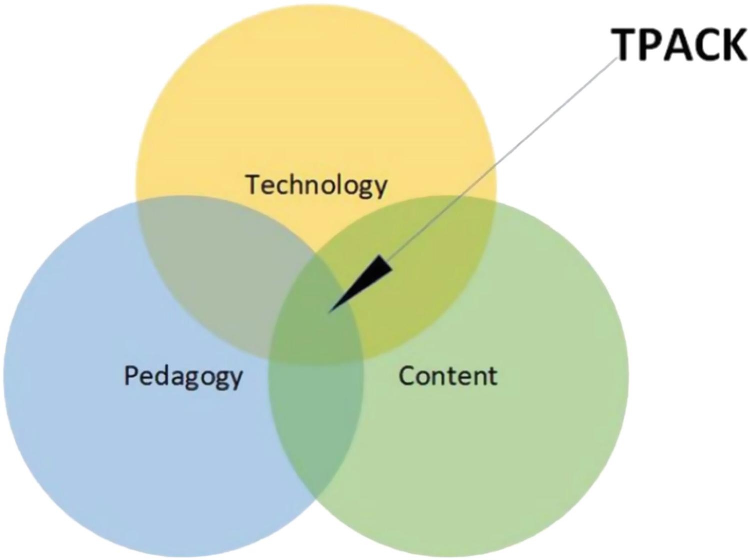

Fig. 3. TPACK Model

Pedagogy it often refers to the teacher-centered approach to educating children and is at odds with the principles of adult learning embedded in the andragogy that it ideally implies students' voluntary commitment to pursue knowledge for its intrinsic value (Pew, 2007). The second element of the model, the content, includes specific knowledge domains education such as health, engineering or law. Technology includes all tools, the software and hardware needed to facilitate online learning. It is through this lens a three ways that this study places the results gathered through this case study.

Facilitating and making the managers of the organization aware of the challenges related to the effective introduction of newcomers is a productivity accelerator; in addition, the active involvement of new hires in improving the onboarding processes that they themselves have experienced develops engagement and a sense of belonging on one hand, and on the other makes the processes themselves even more solid and usable by subsequent new hires.

The field of application was the IT department of Intesasanpaolo, through the development of empirical research.

The interactive approach through the direct participation of management during the execution of the study has optimized the ability to collect the most relevant data for analysis. The collected data, analyzed in combination with the reference theories, were used to explain the challenges of effectively integrating new employees in the organizational growth phase.

3 Methodology

The research design was developed through a case study based on a sample of new hires who entered a specific IT area of the Italian banking group IntesaSanPaolo in the period

2019–2021, through a mixed qualitative and quantitative survey. Data collection was carried out through observation, interviews, some periodic self-reports and the analysis of the onboarding documents compiled jointly with their managers.

4 The Case Study

Starting from the importance of personal enhancement, even in a digital environment, this contribution illustrates how the digitization of the onboarding processes of new graduates within a complex organization can respond to the training needs related to hard skills, but at the same time, to enable a path of insertion of young people in a completely new organizational, cultural, social and productive context, through the articulated and creative use of the technical capabilities that the various company tools offer, for the purpose of enhancing soft skills.

Technology, in addition to allowing companies a more timely and consistent onboarding experience, also responds to the need for eLearning, which has become an almost exclusive tool during the covid19 pandemic. Technology has the ability to bring clarity, efficiency and ease to onboarding.

Technology can also allow onboarding to be more easily customized for the individual as well can allow newcomers to expand their role in the onboarding process (Flanagin & Court, 2007; Ostroff and Kozlowski, 1992). However, virtual onboarding can limit newcomers' social interactions Waldeck, 2004).

Social information is harder to describe explicitly, newcomers often observe the actions and behaviors of others to obtain this type of information (Ahuja & Galvin, 2003; Corte, 2007; Ostroff & Kozlowski, 1992). Remote working makes it more difficult because there is less opportunity for newcomers to watch others interact (Comer, 1991). Newcomers to Intesasanpaolo were reluctant to e-mail to investigate the rules and regulations, but were themselves inclined to use their actuals among other members of the organization by e-mail. Reduced knowledge of organizational norms can affect newcomers' ability to form effective relationships, thereby affecting their performance. Additionally, virtual boarding can limit newcomers' social actions with other members of the organization and reduce the opportunity for proactive social behaviors. Newcomers need to take a proactive approach to onboarding, asking more questions and intentionally creating opportunities for observation. Onboarding is not an individual process, but rather it is a group process involving multiple members of the organization and team. Newcomers continually seek information and feedback from other members of the organization to help them adapt to their new environment and understand whether or not they meet expectations.

The case study refers to the It department of Intesasanpaolo, and in particular to the Domain Investimenti, which in the last 3 years has hired 13 recent graduates and is ready to hire another 199 in the next 30 months.

Since it is an IT structure, a new way of using the usual tools has been implemented, such as microsoft outlook, teams, skype, word, power point, in order to make them instrumental both to the acquisition of hard skills, but at the same time enabling "new socialization practices".

Aware of the importance of socialization processes within organizations, the classic training courses were integrated with:

– Sessions to enable mutual knowledge between newly hired people
– Meetings to set up a community for discussion and knowledge sharing
– Increase in the number and form of surveys administered, structured or not, to detect self-confidence on the objectives assigned, the level of autonomy achieved and any pain points on one's insertion/orientation
– Identification of "Angels" figures (tutor) who had the purpose of driving new hires on practical matters, logistical issues, social life and unwritten rules of the organization
– Significant use of feedback, emoticons during the Group webboards, distance tutoring with "world caffee practice", shared information repositories (via Teams).

Through the practice of the world café and the use of special "cards" shown in Fig. 4, we worked with the new hires on the following dimensions:

Fig. 4. Special "cards"

- create a sense of belonging
- increase collaboration by reducing stress
- develop a sense of responsibility and proactivity
- develop a sense of self-efficacy
- generate satisfaction in people

In order to encourage a climate of mutual feedback, the KUDOS practice was also introduced, to share public compliments to those who stand out for particular results achieved, using Teams Suite.

Some social media was also used, which, integrated with the company tools, allowed the development of moments of "remote" sharing and organizational socialization. Organizational socialization is the process by which individuals acquire the knowledge, skills, attitudes and behaviors necessary to adapt to a new job role (Van Maanen & Schein, 1979).

The educational background of the students, all from recent university courses, facilitated a digital and innovative approach, participating in the first person in the transformation of consolidated modus operandi. A newcomer's time to productivity is not necessarily one trajectory of learning, but a combination of multiple domain (and company) specific knowledge.Virtual onboarding of employees is destined for an increasingly intensive use and for this reason it is important that organizations understand the need to implement innovative tools and techniques, but at the same time also to enhance the aspects of socialization and mutual knowledge, activating a process of multiplying through the new hires themselves, who from users become builders of improvement.

Each new employee periodically maintained an xls file that tracked progress with respect to a pre-set plan, which can be modified by mutual agreement with their supervisor. This operating mode was also defined in order to stimulate the sense of self-efficacy, responsibility and proactiveness of the new employee. Some examples of self monitoring of the progress are shown in Figs. 5, 6, 7, 8, 9, 10 and 11.

	A	B	C	D	E	F	G
1		**Nome** - assunzione xx/xx/xxxx					
2		Platform					
3							
4	L'ADDETTO inserisce una riga per ogni GIORNO \ ATTIVITA' per verificare se in linea con quanto pianificato						
5	DATA	DESCRIZIONE ATTIVITA' SVOLTA	tempo PIANIFICATO (min 0,5 ORE	tempo EFFETTIVO (min 0,5 ORE)	CATEGORIA	APPLICAZIONI BANCA	STREAM TRASVERSALE
6							
7							
8							
9							
10							
11							

Fig. 5. Planning, Final balance

1		Nome - assunzione xx/xx/xxxx					
2		Platform					
3							
4	L'ADDETTO traccia i meeting ricorrenti a cui si è condiviso partecipi						
5	DATA INIZIO	DATA FINE	FREQUENZA	DURATA	TITOLO CALL	OBIETTIVO	TIPO PARTERCIPAZIONE
6			Settimanale	1			Interazione elevata
7			Mensile	1			Interazione media
8			Settimanale	0,5			Nessuna
9			Una tantum	1			Interazione elevata
10			Settimanale	1			Ascolto
11			Settimanale	1			Nessuna
12			Settimanale	0, 45			Interazione media
13			Una tantum				Interazione elevata
14			Una tantum				Interazione elevata

Fig. 6. Calendar

1		Nome - assunzione xx/xx/xxxx					
2		Platform					
3							
4	Il COA valorizza l'elenco delle ABILITA' da raggiungere in relazione al ruolo e alla collocazione, indica le PRIORITA' e le modalità di FRUIZIONE, e l'ADDETTO ne prosegue la compilazione						
5	STREAM TRASVERSALE	ABILITA'	Livello atteso di competenza	Tutor	Scadenza erogazione formazione	NOTE del NEO riguardo la PIANIFICAZIONE dei relativi INCONTRI	Formazione DSI
10	APPLICAZIONI BANCA	Area Finanza	BASSO				
11		Fondi Pensione	BASSO				
12		Fondi Comuni	BASSO				
13		Gestioni Patrimoniali	BASSO				
14		Polizze	BASSO				
15		Advisory (Valore Insieme e Wealth)	MEDIO				
16		Motore di calcolo del rischio finanziario (prodotto e portafoglio) - Integration layer BAIL0	ALTO				
17		Suggerimenti di investimenti (ROBO)	ALTO				
18			BASSO				
19	GOVERNANCE		BASSO				
20			BASSO				
21			MEDIO				
22	PROGETTI		ALTO				
23			MEDIO				
24			ALTO				
25			MEDIO				
26			MEDIO				
27			ALTO				
28			ALTO				
29	INCIDENT MANAGEMENT		MEDIO				
30	SOFT SKILL		ALTO				
31	TECNICA		BASSO				
32			BASSO				

Fig. 7. Skills

1		Nome - assunzione xx/xx/xxxx					
2		Platform					
3			(CTRL)				
4	Il COA definisce l'elenco delle AUTONOMIE da conseguire in relazione al ruolo e alla collocazione, a BREVE, MEDIO, LUNGO termine, e l'ADDETTO ne prosegue la compilazione						
5	STREAM TRASVERSALE	TITOLO / argomento	DETTAGLIO / note	TIPO OBIETTIVO	Tutor	Scadenza	CONSEGUITO
6	PROGETTI	Feedback sui corsi fruiti		trimestrale			
7	SOFT SKILL	Mail e meeting					
9	PROGETTI	Schede rilascio					
10	PROGETTI	Scheda governance					
13	SOFT SKILL	Mappa Ufficio					
14	SOFT SKILL	Teams					

Fig. 8. Expected level of independence

1	TUTTA LA FORMAZIONE COMUNE POSSIBILE, e relativi suggerimenti di PIANIFICAZIONE e TUTOR								
2	SKILL	ID PROGR	ARGOMENTO	LIVELLO DI CONOSCENZA	TUTOR	PERIODO	ENTRO IL 31/12	CHECK	MANSIONARIO
3	tutti	1	la fasi di un progetto						
4	tutti	2	il team building						
5	tutti	3	il capacity plan e lo staffing di progetto						
6	tutti	4	lo studio di fattibilità						
7	tutti	5	spiegazione skill e ruoli in un progetto						
8	tutti	6	gestione della delega						
9	tutti	7	strumenti di office - WORD						
10	tutti	8	strumenti di office - EXCEL						
11	tutti	9	strumenti di office - POWERPOINT						
12	tutti	10	strumenti di office - ACCESS						
13	tutti	11	...						
14	tutti	12	...						
15	tutti	13							
16	tutti	14							

Fig. 9. Knowledge

We felt it was important to give onboarding a fair elapsed, from 6 to 9 months. at the end of each month a semi-structured interview was administered to the new employee, in order to analyze his perception of self-efficacy, autonomy, sense of belonging.

Mese	OBIETTIVI Standard (*da confermare*) FORMAZIONE	APPLICAZIONE	SUPPORTO	SETTAGGIO
Ottobre	30%	30%	30%	10%
Novembre	30%	40%	30%	
Dicembre	30%	40%	30%	
Gennaio				
Febbraio				
Marzo				
Aprile				
Maggio				
Giugno				

Fig. 10. Time allocations

CATEGORIA	AMBITO	STREAM	OBIETTIVI	ELAPSED	PERIODO	AVANZAMENTO	STREAM	
SUPPORTO	x	GOVERNANCE	ALTO	settimanale	1^ MESE	DA AVVIARE	CDC	Centro di competenza
FORMAZIONE	y	KPI	MEDIO	mensile	2^ MESE	IN CORSO	INCIDENT MANAGEMENT	
APPLICAZIONI BANCA	z	VENDORS	BASSO	trimestrale	3^ MESE	FATTO	GOVERNANCE	
SETTAGGIO	w	COMUNICAZIONE			4^ MESE	NON NECESSARIO	PROGETTI	
	j					DESIDERATO	SOFT SKILL	
	altro						TECNICA	
	non applicabile						APPLICAZIONI BANCA	

sheet	Azioni Referente	Azioni Addetto
PIANIFICAZIONE-CONSUNTIVO	consulta	pianifica e consuntiva le propriet attività
Abilità	definisce livello, tutor e scadenza, e ne controlla l'avanzamento	contatta i tutor e pianifica gli incontri
Autonomie	definisce titolo, dettaglio, scadenza e tutor, e ne controlla l'avanzamento	contatta i tutor, pianifica gli incontri, verifica\aggiorna il mansionario
Conoscenze *(FACOLTATIVO)*	individua priorità e tempistiche - attinge per definire le AUTONOMIE	aggiorna la fruizione

Fig. 11. Parameters

5 Statistics

To date, only 1 girl has resigned, 7 boys occupy a role of responsibility, 2 have become Tutors for new hires and 5 have brought significant improvements to the internal onboarding processes. The following Table 1 gives a summary.

Table 1. Current roles and active involvement of the 13 new hires.

id	Name	City	Gender	Contractual status to date	Responsability role	Tutor/"Angel" for following new hires	Reviewer processes&tool for onboarding
1	DS	Bergamo	F	Employee	Yes		
2	DFS	Bologna	F	Employee			Yes
3	GAR	Bologna	F	Employee		Yes	Yes
4	ML	Padova	F	Discharged			
5	BC	Torino	M	Employee			
6	CN	Bologna	M	Employee	Yes		Yes
7	DN	Padova	M	Employee			
8	GP	Bologna	M	Employee	Yes		Yes
9	KV	Bologna	M	Employee			yes
10	SM	Milano	M	Employee	Yes		
11	PS	Milano	F	Employee	Yes	Yes	
12	BS	Milano	M	Employee	Yes		
13	LR	Milano	M	Employee	Yes		

6 Main Results

When applying a structured onboarding process in a fast-growing, high-rise company knowledge intensity, it is important to cultivate and nurture social exchange between employees and therefore maintain the transfer of organizational knowledge.

This empirical research has demonstrated that the implementation of hybrid onboarding paths, through the use of technology aimed at learning, also through innovative and engaging formats, and at the same time the planning of "face to face" meetings is certainly winning. The new hires in this case study were all confident in the use of technology, this was certainly a success factor.

Other theoretical mechanisms through which newcomers successfully adapt and integrate into their new roles include perceived organizational support (Perrot et al., 2016), and person-organization adaptation (Beenen & Pichler, 2014; Cable & Parsons, 2001; Kim et al., 2005). The case study shows that the introduction of new organizational figures, such as the Angels, alongside the managers of the organization, hired and commissioned to supervise the onboarding process, were an effective choice. The use of semi-structured interviews with new hires allowed managers to monitor the increase in the level of autonomy of new hires, thus allowing the assignment of increasingly complex tasks, simultaneously enabling a sense of greater effectiveness in the boy/girl.

The study shows that 7 out of 13 young people then held, at the end of onboarding, a role of responsibility in the organization, two of them became Angels available to subsequent new hires and 5 became active agents of change, making improvements to the process. And tools used for onboarding.

The covid-19 pandemic has forced the entire organization to focus on technology as a key element through which to welcome new people, but giving technology itself a new look, less technical/technological and more oriented towards inclusion, the reduction of distances, to creativity. The people who already belonged to the organization have shown themselves to be more open to welcoming newcomers, especially in stimulating and then collecting suggestions deriving from the field experience by the new generations, consequently improving the previously designed onboarding processes.

Now the real challenge will be to test these new processes and tools in welcoming the hundreds of new hires who are about to arrive, putting into scale what has been done and experienced, because in the meantime the context and the organization have also changed further, they were born new fears and new awareness. And in the end it will always be human beings who will make the difference on the results that will be achieved.

7 Conclusions

The IT department of Intesasanpaolo was able to reap the advantages of technology, combining them with the previous structured onboarding processes, but relying on the fact that Covid19 was offering us a great opportunity: that of responding promptly to a new need, introduced by the healthcare context worldwide, to hire thousands of new collaborators with new techniques and methods. We could choose to postpone or do nothing, we could be frightened by too many changes taking place, both systemic and internal in our organization, but we believed in our experience, in the flexibility of our processes and in the fact that the same new hires could help us in the customize their onboarding. Making them feel part of an "experimental" project has developed an anticipated sense of belonging, which has become a boost for subsequent hires, through the continuous improvement of practices and tools. Our openness to the "culture of error" made us find the courage to dare.

Organizations that are able to accelerate the transition and integration of new hires into their roles have a competitive advantage because they can start benefiting immediately from new hires and their accompanying skills and knowledge for the following groups (Perrot et al., 2016).

The limits of this research are linked to the size of the sample and to the fact that it was a pilot phase, which will then be extended to all subsequent hiring waves. The case study refers to a single organization of an Italian banking reality, therefore it should be extended to larger samples and to a greater number of companies, not only in the Italian territory.

Further studies could also reveal whether the return to a new normal, post covid 19 pandemic, can make remote learning even more flexible, through the modular introduction of in-person sessions, based on the specificities of the context, of the organization. And the single new employee.

Since lack of trust can manifest itself in a virtual context and can hinder the development of positive working relationships, an area of further investigation for research could be linked to investigating how team building or coaching practices can integrate the onboarding processes of new hires, fueling the building of a collective emotional intelligence. In this sense, interesting spaces could also open up for further study on the characteristics of the new leadership (being more intelligent with emotions). Thought, emotion and action are inextricably linked dimensions and emotional intelligence is the skill that allows us to combine thought and emotion in a conscious way, leading us to more effective, intentional, strategic and sustainable behaviors over time.

Covid has sadly taught us, in a brusque and wayout way, how important it is to be flexible. What organizations were forced to implement during the pandemic regarding onboarding processes could be a basis for virtualizing other business production processes as well, considering that many physical workspaces are becoming increasingly virtual. Technology will always be our ally in this transformation, but we must never forget that we, as human beings, are also the result of our social experiences.

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The ARETE Ecosystem for the Creation and Delivery of Open Augmented Reality Educational Resources: The PBIS Case Study

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Abstract. Augmented reality (AR) is rapidly emerging as an increasingly useful technology in educational settings. In the ARETE (Augmented Reality Interactive Educational System) H2020 project, consortium members designed and implemented an ecosystem aimed at supporting teachers in building a collaborative learning environment through the use of AR in order to improve educational experiences. In particular, one of the pilot projects aims to introduce AR into school behavior lessons for the first time, leveraging the Positive Behaviour Intervention and Support (PBIS) methodology. Specifically, in this paper we will discuss the proposed architecture within the ARETE project that incorporates AR technology into the learning process of behavior lessons to support the teaching, practice and reinforcement phases of expected behaviors. Through the combination of different technologies and systems, it is possible to create an example of a technological and innovative ecosystem designed for creating behavioral lessons in AR.

Keywords: augmented reality · positive behaviour · behavioural learning · multi-user applications · PBIS

1 Introduction

In recent years, Augmented Reality (AR) has entered our lives and has spread into our daily activities. This technology is able to influence the way we live through a direct impact on our perceptions by enhancing them in terms of sensitivity and experience. Unlike Virtual Reality (VR) in which the user is fully

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immersed in a computer-created fictional world, in Augmented Reality the real world in which the user is embedded prevails [1]. Computer scientists Paul Milgram and Fumio Kishino introduced the theory of the Real-Virtual Continuum [2] by asserting that there is a continuum between the real and virtual environments: starting from the real environment it is possible to arrive at the virtual environment by passing through augmented reality and virtual reality. Such technologies, although considered to be recent, have far more distant origins. One of the earliest examples of VR, in fact, dates back to the 1950s s with Morton Heling, who created a machine called Sensorama whose goal was to extend the movie experience to all five senses, while in the 1960s, Ivan Sutherland created the first augmented reality viewer.

Today, these technologies are being applied in various contexts (cultural heritage [3], industry [4], medicine [5] and other fields) and particularly in education. The use of Augmented Reality in education, as a support for teachers, is one of the main goals of the H2020 ARETE[1] (Augmented Reality Interactive Educational System) project. ARETE project ensures that an interactive AR content toolkit is developed for the creation of 3D objects based on AR standards. ARETE includes standards-compliant AR/3D data infrastructures for educational purposes to ensure applicability, reproducibility, interoperability, accessibility and sustainability. The purpose of this paper is to show an ecosystem developed within the ARETE project that can support teachers of all levels with the creation and delivery of AR content during lessons. The ARETE ecosystem takes full advantage of the technological advancements in the field of AR to lay the foundation for a ground-breaking approach for competitive and sustainable interactive technologies. The effectiveness of this ecosystem will be tested through the assessment of specific skill sets and behaviors (STEM, English literacy skills and the impact of Positive Behavior Support in Schools).

This paper will discuss the relevant software components that are part of the ecosystem and the standards used to make them interoperable with each other. In particular, specific reference will be made to one of the pilot projects related to behavioral education through the use of the Positive Behaviour Intervention and Support (PBIS) framework [6]. Schools that adopt the PBIS framework teach positive behavior to students in the same way as any other subject. According to PBIS, combining the steps of planning, teaching and reinforcing expected behavior is a more effective way to ensure that all students understand behavioral expectations. This creates a positive environment in which students are taught respect, responsibility and safety.

The paper is structured as follows. Section 2 describes the related work. Section 3 presents the architecture and components of the ARETE ecosystem applied to PBIS. Section 4 gives an example of using the system in PBIS behavioral lessons. Finally, conclusions are given.

[1] https://www.areteproject.eu/.

2 Related Works

Various experiences of using AR in educational settings are reported in the literature. In [7] a study investigating the effects of AR on learning science subjects, shows how the technology contributes on the long-term retention of physics-related concepts and students show interest in AR calling it very useful, realistic and interesting for their learning, helping them to understand and analyze problems. Other studies [8–10] show that AR provides an attractive and functional learning environment that can improve student motivation by making learning a more engaging activity. In the survey [11] an interesting reflection is posed on how AR, although an effective and motivating learning tool, has many aspects that could be improved. Regarding the use of specific AR tools in the context of behavioral interventions [12], most solutions designed for educational purposes are marker-based and use smartphones and tablets. The user experience can be enhanced not only through immersive features, but also through a plurality of interactions and the wealth of information disseminated in the environment. Panciroli, et al., [13] state that AR should be seen as a dynamic edifying and didactic tool. In that sense, effective AR design and development should consider not only the user experience but also the pace, time, space and modes of learning, all of these factors can attribute to higher levels of attainment and reuse of the tools. Recent research survey [14] focused on the readiness of the educators for eXtended Reality (XR) applications in education, revealed the lack of expertise and training for the teachers at all levels, given the urgent need for availability of an XR marketplace and open-source authoring toolkit. The results provided the specific level of educators' awareness on XR applications, which is crucial for the future applications [15].

Over the years, the use of interactive and collaborative learning environments has greatly increased in many fields of education. This is due to the importance of the intrinsic motivation of students that comes from playing the applications [16,17]. Even though most educational AR applications described in the literature are intended to be single-user, researchers have been investigating collaborative AR experiences since the seminal publication of Billinghurst et al. [18]. A systematic literature review [19] on interactive, multi-user and collaborative apps for education shows that there are many studies analysing multi-user educational apps from different point of views. Some of them focus on specific school subjects such as maths [20,21] or sciences [22], while other focus on the analysis of the gameplay style, such as López-Faican et al. [23] that compares competitive vs. collaborative styles and their impact on user communication and motivation, or [24] which is a multi-user geography application where teachers and students play together and answer questions on different topics. However, many of the studies mentioned above do not take into account the human collaboration factor for promoting positive behaviour.

3 ARETE PBIS Ecosystem

The solution that the ARETE project presents is to introduce the use of AR for creating activities in the real environment where the lessons will take place. In the proposed use case, the ecosystem is used for behavioral lessons [25].

The ecosystem of the AR solution for PBIS is based on 3 components (Fig. 1):

1. The use of the MirageXR authoring toolkit, which allows teachers to create the AR educational resources.
2. The Moodle ARETE repository to collect the resources created with MirageXR.
3. The PBIS-AR application that allows students to view resources created with MirageXR with an easier interface and also supports the process of teaching, practicing and reinforcing expected behavior.

The combination of these technologies and systems creates an example of a technological and innovative ecosystem designed for creating behavioral lessons in AR. In the following subsections, these three components and the standards used to make the system interoperable will be shown.

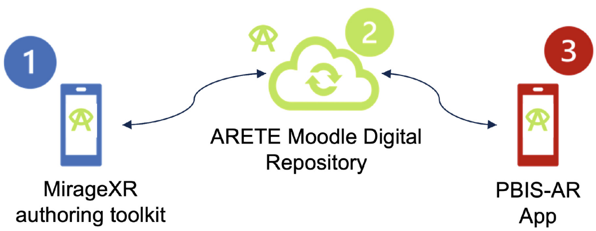

Fig. 1. ARETE PBIS Ecosystem

3.1 Standard Used to Share AR Educational Content

Researching the available interoperability standards that could support the project's needs for creating and sharing AR educational content, the ARETE team came up with the recently published *IEEE Standard for Augmented Reality Learning Experience Model*[2] (ARLEM). The standard provides a conceptual model for the representation of activities, learning context and environment for AR learning applications as well as the corresponding data model specifications, aiming to support the use of AR technology in training and educational systems [26]. Specifically, it aims to facilitate the discovery, retrieval, transfer and execution of

[2] https://standards.ieee.org/ieee/1589/6073/.

interchangeable AR-enabled educational content to support online repositories and marketplaces [26]. ARLEM standard was used by ARETE project to support the interoperability of learning content developed through MirageXR so that it can be stored and executed on different types of platforms and devices. MirageXR has been used as a reference implementation of ARLEM to support the development of the standard by demonstrating the use of the AR authoring tool to create real-life educational applications [27]. Leveraging MirageXR and ARLEM, the ARETE project enables participants to create and exchange standardized and interoperable AR learning content.

To collect and store data, ARLEM uses the Experience API (xAPI) model that allows the collection of data obtained from user experiences. xAPI[3] is a specification that facilitates the documentation and communication of user interactions with the system and uses a specific structure to define experiences labeled as statements. The format of a statement is actor, verb (action) and object, where actor indicates which user performed an action, verb describes the action performed by the user and the object defines the thing that was acted on. xAPI provides an interoperable layer to track users' activities and facilitate the development of learning analytics tools. The use of this specification can support the development of comprehensive views of the individual's learning [28]. Once captured, the data/statement is stored in a Learning Record Store (LRS), ready to be consumed through learning analytics applications. A LRS is a repository for learning records that can be stand-alone or part of an Learning Management System (LMS) or other learning systems. In Learning Analytics (LA), data quality is a key issue and xAPIs play an important role in the processes of collecting and storing events in the LRS. In the ARETE project, the LRS that has been adopted is Learning Locker[4], developed by H2T Labs™. The statements to be recorded are defined at the application level and can be customized, and Learning Locker also provides a user interface to access all collected data. In particular, dashboards are available to perform in-depth analysis of the collected statements and custom queries.

3.2 MirageXR in a Teacher's Perspective

MirageXR[5] is designed for creating and experiencing augmented reality activities. For the ARETE project MirageXR is used by teachers as an authoring toolkit, providing them with the tools required to create their own educational activities for their students in AR. The practicality of Mirage is in its structure, every activity is split into steps which each contain augmentations which are the augmented reality content. Splitting activities up into steps this way allows teachers to create a clear narrative with progression through the activity. The augmentations come in a few different forms, some are more rudimentary such as labels and images whereas others provide much more advanced AR feedback making true use of the medium.

[3] https://xapi.com/.
[4] https://learninglocker.atlassian.net/wiki/spaces/DOCS/overview.
[5] https://wekit-ecs.com/documents/miragexr.

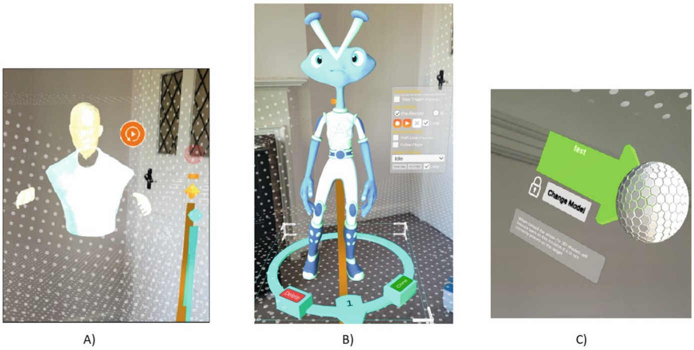

Fig. 2. Mirage Augmentations. A) Ghost, B) Character, C)Pick and Place

For example the ghost augmentation (Fig. 2 A) can record the voice and movements of the author while performing a task, this is then played back at real time speed via a 3D avatar which mimics the author's hand and body movements. Another augmentation worth noting would be the AI Character model (Fig. 2 B) which can be designed to either repeat predefined audio recording or respond dynamically to conversation via IBM Watson[6]. Character models can also move along set paths avoiding obstacles or can be told to follow the current activity user. In order to aid the learner, character models have a predefined set of animations they can perform such as wave, point, and image display in which they hold up a card showing an image. Pick and Place (Fig. 2 C) is another augmentation designed for teachers and is currently the only objective based augmentation in Mirage. From an author's point of view the pick and place augmentation has two objects: a target and an arrow. The goal for the learner is for the arrow to be placed correctly in the target. The arrow object can also be changed to mimic any 3D model available on Sketchfab, this means this augmentation can be used to pin flags on a map or to add labels to parts of the brain. Once an activity has been created an author can then upload it to the Moodle repository where it can be downloaded by students.

Through the use of MirageXR teachers have been afforded the role of authorship administration, thereby enabling them to develop their own teaching and learning experiences. This has offered teachers the opportunities to craft learning experiences to match their students learning needs. Linked with Moodle learning repository, MirageXR has focused on usability making new user interactions with the interface more enjoyable. The impact of this is the teachers focus is

[6] https://www.ibm.com/it-it/cloud/watson-text-to-speech?lnk=flatitem.

directly on the content of the learning experiences. The increased accessibility of MirageXR is designed to attract more teachers to feel more at ease when working with the application on-the-fly.

MirageXR, also holds the potential to become a shared resource, a resource for teachers to use to collaborate in the development of learning experiences. By uploading the content of the learning activity into Moodle, other teachers can contribute to a particular activity or to use a finished learning activity. The collaborative nature of augmenting learning could result in the development of a rich battery of learning activities, as well as a convenient teaching resource, that could inspire new pre-service as well as long standing in service professionals.

3.3 ARETE Moodle

Within the educational context, there is a growing body of evidence of the impacts of informal education on learners – e.g., valuing science and the natural environment, increasing self-efficacy, making scientifically influenced decisions and developing 21st century skills. Knowledge about informal learning experiences is published in the fields of science education and has become increasingly accessible to the STEM research community in repositories such as InformalScience.org. The data management landscape for educational initiatives in Europe is characterised by a very large number of individual and domain-specific data initiatives and scientific databases, with only a small number of the data initiatives federated. Long-term sustainability is a major issue for all data initiatives, and not only a problem limited to the underlying hardware infrastructure but also for the software access and exploiting the data. Current e-learning systems focus on the data infrastructures only and not on the content management for 3D reconstruction and visualisation associated with teaching and learning. A key barrier to adoption of XR in the classroom is the lack of XR-enabled content, the affordability of hardware and the lack of understanding of pedagogical arrangements that teachers need to put in place to be able to integrate AR in their teaching. To address this and to facilitate the design of XR content that will be well aligned to the curriculum, ARETE team has further developed the MirageXR software, also complementing it with a plugin for Moodle[7], an open-source learning platform, to enable teachers to manage and schedule content efficiently. Interoperability issues in data management are very important to ensure that scientific data is reachable and useful to other scientific fields, i.e. to enable cross-disciplinary data intensive science.

ARETE promotes development and access to AR 3D content data that has not yet become a reality in many scientific domains and it will facilitate effective and efficient use of digital content through the open source availability of both the platform and the 3D content ARETE Marketplace. It provides mechanisms to collect, manage and process data from multiple abstractions adhering to standards of learning objects. Through the digital learning ecosystem, both

[7] https://arete.ucd.ie/.

content-based data and educational data, in all their diversity and complexity, can be integrated.

3.4 PBIS-AR App

The PBIS-AR application is designed for students and leverages AR technology in the behavioral lesson learning process to support the teaching, practice, and reinforcement phases of expected behaviors in the school environment. The architecture of the PBIS-AR application consists of several modules, each devoted to a specific function and described below.

Intro App, Authentication and Setup. The student is introduced to the use of the application through a dialogue with an alien named Arpro that is the main character of the app. The alien introduces himself and begins an interactive dialogue with the user. The first time the system is started, a setup procedure will be run by the teacher to specify the school and the Moodle account from which to take the information needed to use the app, like for example animations created using MirageXR. The student will have to enter the nickname provided by the teacher, which will be used to track the interactions thus maintaining users' anonymity.

Teach Section - Play Behavioural Routines. In this section, the student can play routines created by the teacher through the use of the MirageXR toolkit and stored in the Arete Moodle server according to the ARLEM standard. The student will select one of the behavioral expectations from a list (see Fig. 3) based on the behavioral lesson conducted by the teacher and view the content in augmented reality without the use of markers, but relying on environmental mapping. The content then is a 3D animation contextualized in the school environment. These animations have the alien as the main character and secondary characters such as teachers or students engaging in the display of routines.

Discovery Section - Behavioural Reflexive Game in AR. The discovery section allow students to access reflective games with the aim of practicing and reinforcing expected behaviors. The teacher will place markers in the school environment, and the student, by framing them with the device's camera, will view animations related to expected and unexpected behaviors. At the end of the animation, the student will display a dialog box with a question and answers. Based on the student's answer, a score will be given. The points earned will allow only the top 3 students to be ranked and displayed on a podium and to recognize student achievements and motivate them, avoiding the use of a ranking so as not to discourage students at the bottom of the list. These points will be accumulated with those in the practice section.

Fig. 3. Behavioural expectation list

Practice Section - Multiuser Activities Within Behavioural Lessons. In this section, students can experience collaborative learning activities to improve their behavioral skills. This section is composed of a main screen (see Fig. 4 A) in which the students find a menu with four activities prepared to work in pairs. Before selecting one of them, they have to select a group so that they are connected to the session they have been assigned. And then, both students in each group choose one of the four activities in the menu.

The four activities have been designed so that students can interact with each other in the augmented space in different ways. These activities are the following:

- Greeting others: This is a role-play game in which students learn how to greet the other (See Fig. 4 B). First of all, the students select a character that is shown virtually once a marker is scanned. Once both students are connected, they have to answer a quiz that asks them how to greet each other. When both students select their answer the augmented characters show the greetings through synchronised animations. If the answer is correct they earn some points and if it is not, they have two additional attempts, where in case of success they earn less points than in the first attempt.
- Stand up for others: This is a second role-play game in which students learn how to behave when they witness a bullying scene involving one of their colleagues (See Fig. 4 C). Again, first of all, both students select a character that is shown virtually once a marker is scanned. These characters are considered helpers and have to decide what to do once they see a scene in which a group of students is laughing at a colleague. The actions are selected through a quiz and once both students answer the characters show synchronised animations. This activity includes also the rewarding system explained in the previous case.

– Keep the workspace organised (Untidy version): In this markerless activity, students learn in pairs how to organise the workspace interacting with virtual objects they see after scanning a real surface such as a table (See Fig. 4 D). Once the surface is scanned, a virtual drawer is shown with disorganised school material and students are asked to take the maths book which is at the bottom and is not accessible in the first attempt. Once they achieve the goal they have to answer some questions to reflect about the time they needed to complete the task. And finally, they are asked to store all the objects they took out unnecessarily. Finally, when only the maths book is left on the surface, the application tells them they are ready for the lesson.
– Keep the workspace organised (Tidy version): This is a similar activity to the previous one but the lesson is addressed from the opposite point of view. In this case a tidy drawer is shown and the same task is requested, i.e. to take the maths book. The maths book is accessible directly and once they take it out, they have to answer a quiz to reflect again about the time they spent to complete the task.

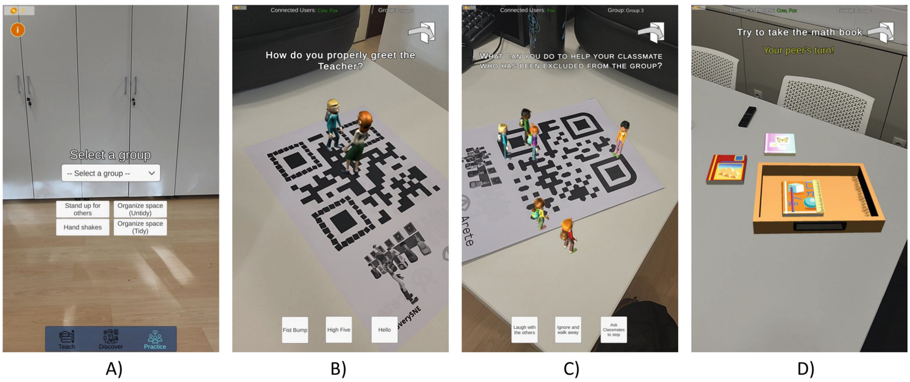

Fig. 4. Screenshots of the multi-user activities in the PBIS AR app. A) Main menu; B) Greet others; C) Stand up for others; D) Keep your workspace organised

All the interactions between users have been implemented through the Orkestra library, which provides communication between users connected to the same session and ensures coherence at the augmented space. More in detail, Orkestra is a technology agnostic library composed of a client side, called OrkestraLib, where most of the logic that allows multi-user communication and synchronisation is implemented, and a server side called OrkestraServer, which manages all the connections, messages and sessions of the users. In this case, a CSharp client of OrkestraLib has been integrated in the application, OrkestraServer has been deployed in AWS, and all the communication between both parts is done through web-sockets.

Regarding the features that Orkestra provides we could highlight:

– Session generation: it allows to create different isolated sessions though unique session and user IDs so that students can work in pairs without interfering with the other groups.
– Real time communication: it is possible to send messages between users in real time.
– Synchronisation: it allows the synchronisation of each activity between users and devices.
– Simple interactions: it provides the possibility to implement interactions that require a single message sharing to show the same behavior on both screens.
– Advanced interactions: it provides the possibility to implement interactions that require a lot of messages per second to track the movement of 3D objects and obtain a smooth and coherent interaction in both screens.
– Connection control: it allows to check the connection of users in the same session during the game so that in case one user is disconnected the other can not continue playing alone.

All of this will allow the students to do the exercises together, interacting in the augmented space which will improve their learning experience as seen in Fig. 5.

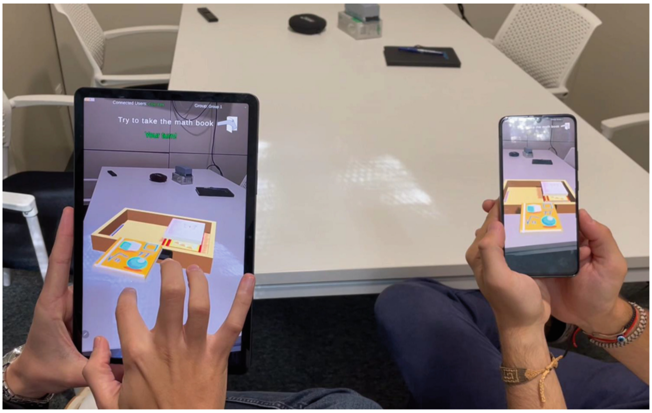

Fig. 5. Multi-user PBIS AR experience

4 ARETE PBIS Pilot

Following the design process carried out together with PBIS teachers from various European PBIS schools, behavioral expectations were chosen to be included within the pilot. In this section we report an example of using the ARETE ecosystem for the behavioral expectation “Stand up for others”. The teacher with the support of these systems can design and implement an Augmented

Reality Behavioural Learning Resource (AR-BLR) that models an example of expected behaviour. A good behavioural example is thus a 3D learning resource in the form of an AR animation built in the specific environment in which the teacher expects this behavioural expectation will be applied.

To create the behavioral resource and use it within his lesson "Stand up for others", the teacher will need to perform the following steps:

– Create the AR-BLR using the AR toolkit MirageXR
– Publish AR-BLR in the Moodle ARETE repository
– Use the PBIS-AR application to view the AR-BLR

In this example, the teacher wants to make a behavioral learning resource that models a good example of behavior. So the 3D animation should show Arpro, the alien character, standing up for a classmate who is being teased by two other students.

Table 1 describes a behavioural routine realisable with the MirageXR authoring toolkit using a single step.

Preparing this table helps the teacher design the activity, as in a script: which characters to introduce into the scene; how many MirageXR steps are needed to realise the scenario; the animations to be selected in the various characters and the actions to be performed in each step to realise the behavioural scene. The Fig. 6 shows an editing use of MirageXR for creating the AR-BLR "Stand up for others".

Fig. 6. MirageXR teacher's authoring activity

Once the resource has been created, the teacher may decide to save the resource locally in the device or in the ARETE repository using his or her credentials. The behavioural resource is then saved on the ARETE repository and available to its students via the PBIS-AR application. At the teacher's instruction,

Table 1. Stand up for others routine description

Scenario Title	Stand up for others
Example or Non Example	Example
Short description	Two students are standing together on the corridor and ostracize another student (victim). The two students are laughing and whispering. Arpro sees this, walks up to the students and indicates that they should not be mean to the victim.
Setting	All settings/Social skills
Phase of the lesson where to be use the AR resource	Modeling/teach phase
Numbers of steps	1
Characters models	Students, Arpro
Character Animations to be use	Student 1 (victim): idle Student 2: Laugh stand Student 3: Whisper stand Arpro: walk from point A to the perpetrators
Step [1] creation	Position one student victim on a side and set the idle animation. Put two students (ST1 and ST2) on the other side in front of the victim and one next to the other. Set the ST2 “Wisper stand” animation. Set the“Laughter Stand” animation so that the other (ST1) laughs at the victim. Put Arpro before the group, clone it and move the Arpro number 2 next to the two students and select the “No gesture” animation.

the student selects the behavioral expectation from the list accessible through the Teach section and views the list of behavioural resources created by the teacher for that lesson. Once the resource is selected, the student is able to play the AR animation and view the behavioural example of the specific behavioural expectation.

Figure 7 shows two frames of the AR animation created by the teacher in action within the PBIS-AR application. The image on the left shows a frame of the AR animation in which the students tease the victim, while the frame on the right depicts the arrival of Arpro who asks them to stop teasing their peer.

Fig. 7. Using "Stand up for others" AR-BLR in the PBIS-AR application

5 Conclusion

This paper presents the AR ecosystem developed within the H2020 ARETE project. Specifically, it has been applied within pilot #3 in which Augmented Reality will be used as support during behavioral lessons according to the PBIS method. One of the main goals is to achieve an interoperable and innovative system that engages students and encourages them during the process of learning behavioral rules. To obtain the ecosystem, new standards and AR technologies were adopted for creating educational activities in the school context by proposing multi-user interaction activities and tracking their interactions with the system. Currently, the ecosystem is being tested in some European schools where the PBIS framework has been adopted. The proposed AR solution for behavioral education provides an excellent starting point for the creation of an AR ecosystem for education. In fact, such an ecosystem can be adapted to different contexts and not only the behavioral one.

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Flipping the Laboratory in an Academic Course on Object-Oriented Paradigm

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Abstract. This paper reports an application of a teaching strategy based on a flipped classroom approach for laboratory sessions of a second-year programming university course, *Programming II*, held at the University of Bari and focused on the OOP paradigm. In our experience, this approach lets the students train to implement programs on their own before coming to class. Here, they will apply the knowledge during face-to-face lessons to elaborate, reflect and compare on what has been learned. We provided an evaluation of the approach through a quasi-experiment aiming at comparing two groups of students: one followed laboratory sessions by a flipped classroom approach and the other one by the traditional approach. Results show that the flipped group helps to produce better source code than the traditional group over the course of the time.

Keywords: Flipped Training · Education · Object-Oriented programming · Computer aided instruction

1 Introduction

Several obstacles characterize the activity of teaching courses based on Object-Oriented paradigm [1]. The adoption of software development principles, practices, tools, and the application of learning analytics approaches [2–4] are needed to overcome these obstacles. All this, however, is not enough, a continuous research of new teaching strategies to improve long-term student retention is necessary. Moreover, since every programming course aims at teaching students how to write a program, the laboratory sessions play a key role for executing it. Most studies on flipped classroom in the field of computer science apply the methodology to the theoretical classes, and therefore neglect its potential benefits and limitations in the context of laboratories. Only a few papers report results on flipping the laboratories of computer sciences courses, although they are not the focus of their work and so they miss the potential gains and drawbacks. Motivated by this consideration, this article reports the application of flipped to the laboratory sessions of a computer science course. In this work, we aim to understand if a teaching strategy as the flipped classroom used for the laboratory sessions could improve students' performances on applying programming concepts for a development task.

In this regard, the purpose of this study was to explore the flipped classroom approach as a digital pedagogy to enhance students' performances on programming tasks provided

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in a focused Object-Oriented course held at the University of Bari Aldo Moro. The main research question was: *do the performances of the students in a programming task in the context of a Programming II course increase when trained by the flipped approach compared to the traditional approach?*

The remainder of the paper is organized as follows. In the next section, the background of the flipped classroom is described, while Sect. 3 briefly discusses the main related work. Section 4 deals with the empirical study carried out. Results and discussion are presented in Sect. 5. Finally, Sect. 6 draws the conclusions and suggests future work.

2 Background

The pandemic period that began in March 2020 has revealed that pre-existing teaching will always have a key role in the lives of students, above all because it plays a fundamental educational function. The experience forced by the pandemic has highlighted that it becomes increasingly important to talk about planning and the balance between synchronous and asynchronous didactic activities which, even if they follow completely different methods and logics. Here, there is a common goal: to create a school with a complete educational and inclusive value.

Digital teaching responds to these needs with different teaching models, such as Blended Learning, Cooperative Learning or Flipped Learning. The latter modality is increasingly capturing the attention of the training world because it allows students to become protagonists responsible for their own educational success, while the teacher takes on the takes on a guidance role in their educational path. In fact, the flipped classroom approach is a technology-enhanced pedagogy characterized by two basic teaching strategies: problem-solving and peer-assisted learning [5–7].

The methodological approach of the flipped classroom involves the inversion of the traditional learning cycle made up of lectures, individual study at home and tests in the classroom. The Flipped Classroom consists of two key moments:

1 each student learns independently, supported by the use of multimedia tools;
2 the class meets at school and the teacher organizes a lesson aimed at putting into practice the knowledge that the students have learned independently.

The idea behind this mode is that the lesson becomes homework, while the time in the classroom is dedicated to collaborative activities, experiences, workshops, and debates [8]. In this context, the teacher does not take a leadership role, but rather becomes a sort of facilitator or the director of the didactic action. During the time at home, videos, and other digital resources, such as lecture slides, are widely used as contents to study, while in the classroom students experiment, collaborate, and carry out laboratory activities. To all intents and purposes "flipping" is a didactic methodology to be used in a fluid and flexible way, regardless of the discipline or type of subject.

A first principle on which this methodology is based is active and collaborative learning through which the student does not passively receive the notions, but elaborates them reflecting on them and, perhaps, applies them.

A second principle concerns the anticipation of content: the study topics are in fact anticipated through different materials that the student views and studies at home and then already have knowledge of them when setting up classroom work.

A third principle is to support the use of new technologies which, among other things, are increasingly familiar to learners.

With flipped, the contents are prepared by the teacher and studied at home by the learners, later becoming material for the subsequent face-to-face work done in class.

3 Related Work

A recent systematic literature review [9] proved that this approach promotes flexibility to both teachers and students at various level to improve their speaking skills. Students are accountable towards their own learning process, collaborated between one another and share ideas inside and outside of classroom. This increases the speaking opportunities and promotes active learning. It cannot be denied that the flipped learning approach promotes a better conducive learning environment to teach speaking skills.

More studies in the literature [10–13] show a positive trend of flipped classrooms in regard to effectiveness of the method. These classes are also having a positive effect on students' performance, attitude, cognitive abilities, and soft skills as they take more responsibility for their own learning.

Recently, the flipped classroom approach has been applied in different subject disciplines, such as medical education [14, 15], language education [16, 17], and mathematics education [18–20].

The theoretical framework surrounding adaptive learning focuses on the belief that long-term educational success and development starts with adapting instruction to individual student needs. However, the longer-term goal is for students to learn to adapt to instruction and become self-regulating.

The many experiments in the literature show that one of the negative aspects of flipped learning is the quality of the contents delivered to students for the first phase of individual study [11, 17, 18, 21]. Furthermore, it is often pointed out that these contents, currently the same for all students, should, on the other hand, adapt to the level of preparation reached, gradually, by the learner [22]. In this sense, several papers show the adoption of adaptive learning software to customize the first step of the flipped classroom. With this service/software we intend to automatically monitor the student's progress during a lesson and adapt the instruction to the student's needs based on his performance. Each student thus encounters a rhythm and an individualized learning path, which includes videos, textual instructions, graphics, simulations, and assessments with immediate feedback.

Adaptive learning is a technique for providing personalized learning, which aims to provide efficient, effective, and personalized learning pathways to engage each learner [22]. It dynamically adapts to student interactions and performance levels, delivering the types of content in an appropriate sequence that individual students need at specific times to make progress [23]. These systems use algorithms, assessments, student feedback, instructor adjustments/interventions, and various media to provide new learning material to students who have mastered and remediate those who have not.

The intrinsic strength of adaptive learning thus finds its natural completion in flipped learning [24].

4 Experiment

In our empirical investigation the assignment to a given treatment condition (flipped or traditional approach) is based on an initial skill assessment test. As a result, we carried out a quasi-experiment [22]. In this section, goal, context, variables, research hypothesis and the empirical design are described.

4.1 Goal

The goal of the study is to investigate the differences between the Flipped approach and a traditional approach to evaluate if it supports programming tasks effectively and allows students to improve their performances (in terms of score in performing programming activities). The quality focus regards how these approaches affect the capability of students to correctly write the code.

We used the Goal-Question-Metric template [25] to define the experiment. The goal is defined as follows:

"Analyze the use of different teaching approaches to evaluate the performance of the students who execute a programming task in the context of a CR2 programming course."

4.2 Context

The students involved in the experiment come from a programming course held in the Computer Science Engineering bachelor's degree at the University of Bari Aldo Moro during the academic year 2020–2021. It is a compulsory course for all second-year computer science engineering students at this institution. The students are re-quired to pass the previous programming course to be enrolled in this course. This ensures that all the students have a similar academic background. Furthermore, since students could have different programming skills and abilities, they were asked to answer a profiling questionnaire and to participate in an "initial skill assessment test." In the profiling questionnaire, we asked students which exams they had already passed and what was their current average academic score. Since we are interested in studying the effect on programming accuracy after training subjects with the proposed approach, only students that had no previous experience in object-oriented tasks were involved in the study. For this reason, all students who, at the beginning of the empirical investigation, have already experienced with an object-oriented programming language were not involved in the study. There is no course in the first year and in the first semester of the second year, where Object-Oriented is taught. This requirement ensures us that all the students have a similar background on the Object-Oriented topic.

In the initial assessment test, subjects were asked to complete tasks consisting of 10 exercises of code understanding and development activities to ensure that they were able to understand the language concepts needed to approach programming. According to the results obtained in this test and the profiling questionnaire, we classified the subjects into two categories: high ability subjects (HAS) are those who already had experience with software system development, have an average academic score of at least 25/30, and completed correctly at least 50% of the tasks; the remaining subjects that completed correctly at least the compulsory portion of the assignment (25% of the tasks) are classified as low ability subjects (LAS). The rest of the subjects were excluded. Those students that completed less than 25% of the tasks, were excluded because we thought their low ability in understanding and developing activities could have affect-ed the study results. Finally, it is important to specify that, for students who already had experience with software system development, we mean those who passed the programming language course. Specifically, 118 students were enrolled in the Programming II course held in the first semester of 2021. From this set, after the initial skill assessment test and a profiling questionnaire, 72 students were selected to participate in the experiment.

4.3 Hypothesis Formulation

The null hypotheses (H_0) to be tested is defined as follows: *there is no statistically significant difference in the efficacy of a programming task between students that have learned using either Flipped or Traditional.*

It is important to highlight that, on one hand, Flipped intentionally uses time in the classroom to explore topics in greater depth and create meaningful learning opportunities while students are initially introduced to new topics outside of the classroom, whereas Traditional typically has the teacher as the primary disseminator of information during the class period. On the other hand, the Flipped approach requires students to be motivated to learn the content, the material must be engaging and interesting. Videos should encourage students to not only watch the words but also to listen to them. For these reasons, we do not have any idea if Flipped approach improves or worsens in performing the programming task when compared to the Traditional approach. Therefore, a two-sided test is required because the alternative hypotheses against which the null hypothesis (H0) is tested stipulate that the first group data distribution differs from the second group data distribution. A null hypothesis, in this case, is rejected if scores of one group are significantly larger than those of the other group. No specification is provided about the direction of this difference.

4.4 Variables Selection

There is one dependent variable: programming accuracy. To measure it, we asked subjects to develop a little Java program starting from a set of requirements. Students had to apply in the right way the concepts and constructs learned during the lessons. The set of requirements were defined satisfying the following constraints:

- they are no longer than one page.
- they are exclusively related to language aspects and technologies covered by the course (no extra knowledge is required).
- due to time reasons, they do not require to implement graphical user interface and access to any kind of data source.

- they require to achieve abstraction by defining an Interface, an Abstract class derived from this Interface, and 2 or 3, depending on the specific task, concrete classes derived from the abstract class.
- they require, to encapsulate operations that are not specific to a particular data type, to define a generic class over the interface previously defined.
- they require to implement, in the generic class, a Comparator or Comparable interface to order the objects of user-defined classes.
- they require to define per each class only attributes listed on the assignment.
- they require to apply, in the generic class, association relationship between classes by choosing the most adequate container
- they require to define a main class to test all the methods defined for the generic class.
- they can be implemented using the time available.

We measured the accuracy of programming using a score between 0 and 10, where zero means that the program was not developed and ten that the program was completely and correctly implemented. To evaluate solutions' accuracy, we involved three senior lecturers to mitigate the solution evaluation bias of using a single senior lecturer. Each lecturer made independent evaluations. They compared the solution with the correct and complete one defined by the teachers looking at the process they followed and the reasoning underlying the choices. The final scores were computed as the average of the scores given by the three lectures. The independent variable, that is the main factor of the experiment, is the training strategy received before the execution of programming tasks. The two alternative treatments are as follows:

(1) Flipped, for subjects trained by the flipped approach.
(2) Traditional, for subjects trained by the traditional approach.

4.5 Experimental Design

To keep control and treatment groups separate, the proposed quasi-experiment is a between-subjects design. The experiment consisted of four experimental sessions requiring one Java software system to be developed starting from a set of requirements. The structure of the quasi-experiment is depicted in Table 1.

Subjects Assignment. The allotment of participants to the groups was made by satisfying the criterion that each group was composed by the same number of LAS and HAS students. Since the requirements to implement could interact with the main factor, we decided to use a wider range of requirements splitting both GroupFlipped and GroupTraditional into two disjoint groups, respectively, $Group_1$ and $Group_2$ for GroupFlipped and $Group_3$ and $Group_4$ for GroupTraditional. All these groups contained 18 participants balanced for ability.

Experimental Sessions. The experiment is structured as a sequence of four sessions ($Mark_1$, Lab_1, Lab_2, $Mark_2$). $Mark_1$ and $Mark_2$ are, respectively, the pre-test and post-test programming sessions where all the students use the traditional approach. In sessions Lab_1 and Lab_2, instead, the students of GroupFlipped used the Flipped approach while those of GroupTraditional use the traditional approach. Different development assignments (R_1, R_2, R_3, R_4) are assigned during the sessions ensuring that each group performs developing one time on each set of requirements. The mapping among groups, requirements to be implemented, and sessions are reported in the table below.

Table 1. Experimental Design of the Quasi-Experiment

	GroupFlipped		GroupTraditional	
	$Group_1$ (9 HAS, 9 LAS)	$Group_2$ (9 HAS, 9 LAS)	$Group_3$ (9 HAS, 9 LAS)	$Group_4$ (9 HAS, 9 LAS)
$Mark_1$	R_1	R_2	R_1	R_2
Lab_1	R_3	R_4	R_3	R_4
Lab_2	R_4	R_3	R_4	R_3
$Mark_2$	R_2	R_1	R_2	R_1

Figure 1, instead, reports the overall structure of this investigation.

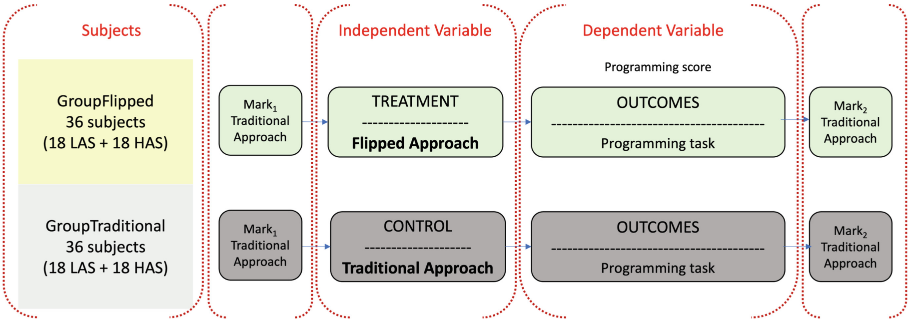

Fig. 1. The overall structure of the empirical design.

4.6 Experimental Procedure and Material

The teaching materials provided to all students were:

- lecture slides providing the basic definitions of the Object-Oriented concepts: abstraction, encapsulation, inheritance, types and generic types, different forms of polymorphism such as overloading, coercion, sub-typing, and parameterization.
- examples and practices on the Object-Oriented concepts given by the teachers during the course.

Students of FlippedGroup were also provided with 2 groups of videos, one for each training laboratory followed by flipped approach (R_3-R_4). Each video conveys the key evaluations to decide how to implement a development task, whose requirements are defined following the constraints listed in Sect. 4.3, in a Java program.

To make the videos attractive, we followed some of the recommendations provided by [26] and reported below:

- teachers segmented videos into short chunks, all less than 6 min.
- the teacher's head were recorded and then inserted into the presentation video at opportune times.
- when slides or code had to be displayed, teachers added emphasis by sketching over the slides and code using a digital tablet.
- support for rewatching and skimming videos was provided.
- a conversational, enthusiastic style to enhance engagement.
- audio and visual elements used in combination to convey parts of an explanation; relevant ideas or concepts appropriately highlighted.

In total, 12 videos were produced, 6 for each training laboratory. The shortest one with a duration of $2'34''$ and the longest one $5'45$.” The average length of the videos was $3'58$”.

The laboratory lessons (flipped and traditional) were carried out in parallel according to the scheme of Table 2 where the second and third columns list the tasks to do by, respectively, FlippedGroup and TraditionalGroup.

In the last lesson of the seventh and eight weeks of lessons, the students were assigned a laboratory development task.

Table 2. Flipped class schedule

Week number	FlippedGroup	TraditionalGroup
1st lesson of the semester	A brief explanation to students on how to do the lab sessions	
First five weeks of lessons	Learn the topics following the teacher's lessons	
Week n. 6 2nd lesson	$Mark_1$: Training laboratory supported by Teacher	
Week n. 7/8 1st lesson	Training laboratory on their own	Training laboratory supported by Teacher
Week n. 7/8 2nd lesson of the week	Flipped Lesson (an activity, conducted by the teacher, of elaboration, reflection, and comparison on what has been learned)	Reflection on their own
Week n. 7/8 3rd Lesson of the week	Development task (Laboratory session- 2 h)	
Week n. 9 2nd lesson	$Mark_2$: Training laboratory supported by Teacher	

The programs were collected by the tutors for marking. The following section briefly presents the preliminary results and a discussion of them.

4.7 Analysis Method

We applied the Mann-Whitney U two-tailed test since the following hold:

- programming accuracy is measured at continuous level.
- the training strategy consists of two independent groups (FlippedGroup and TraditionalGroup).
- independence of observations, there are different participants in the two groups and each participant belongs to only one group.
- distributions of groups are not normally distributed.

We assumed a significance level of 0.05 to check the statistical significance differences of experimental results.

To evaluate the effect size of the difference we used Cliff's delta non-parametric effect size measure. Such a measure quantifies the amount of difference between two groups of observations and provides a useful complementary analysis for the corresponding hypothesis testing. Cliff's delta assumes values in the range [-1, + 1]. Values near the lower and upper range indicate the absence of overlap between the two groups, while values near zero indicate a strong overlap between the two groups. To investigate if Flipped treatment was more or less effective than the traditional training, we compared the two groups on the empirical session whose time-scheduling is in the fifth row of Table 2.

5 Results and Discussion

This section presents the empirical results, and limitations to the validity of the empirical study. We used the R environment to perform the statistical analysis.

5.1 Testing Hypotheses on Programming Performances

To address the research question, we used the programming task aimed at evaluating the accuracy of the proposed solution by the students, manually evaluated by the teachers. The descriptive statistics related to $Mark_2$, reported in Table 3, reveal that accuracy of programming obtained by students that have used the Flipped approach during the course was higher than in the other case (Traditional) while those related to Mark1 reveal that initial accuracy was similar. Taking the descriptive statistics in their entirety it is possible to say that programming accuracy grows in both approaches, faster in the flipped group.

Table 3. Descriptive statistics for all laboratory sessions

Session	Group	Mean	Standard deviation
$Mark_1$	Flipped	14.4	1.3
	Traditional	14.3	1.1
Lab1	Flipped	17.8	1.5
	Traditional	17.4	1.4
Lab_2	Flipped	20.9	1.4
	Traditional	19.8	1.7
$Mark_2$	Flipped	24.5	3.4
	Traditional	22.9	3.7

The rows "FlippedGroup vs. TraditionalGroup" of Table 4 shows the results of the t-test executed for the running session carried out comparing the programming accuracy for groups Learning and Flipped. This table also reports, at the third column, the effect size of the difference using Cliff's delta non-parametric effect size measure [24]. We compared the two groups across different marks (i.e., Flipped at $Mark_2$ with respect to Flipped for Mark1 and Traditional at $Mark_2$ with respect to Traditional at $Mark_1$). This to reject the null hypothesis that states that the flipped had no effect on programming performances (second and third rows in the table). We also compared the two groups on the same marks (first and fourth rows in the table) to:

- ensure that the subjects were correctly balanced and did not start with a significant difference in performances ($Mark_1$).
- investigate if Flipped treatment was more effective with respect to Traditional training ($Mark_2$).

As the Table 4 shows, the level of significance of the test is, for both Flipped and Traditional at $Mark_2$ versus Flipped and Traditional at all marks, over 95%. Conversely, the level of significance is below 95% for.

- Flipped at $Mark_1$ and Traditional at $Mark_1$—meaning that there is no difference in both groups' performances (Flipped and Traditional) at Mark1 (i.e., before the flipped approach).

Finally, the level of significance of the test for Traditional groups across $Mark_2$ and $Mark_1$ is over 95%. It means that, although to a lesser extent than Flipped approach, the usage of a traditional approach for laboratory sessions had significant effects on accuracy.

Table 4. Results of the *t*-Test

Comparisons	Accuracy programming	
	p-value	Cliff's Delta
FlippedGroup $Mark_1$ vs. TraditionalGroup $Mark_1$	0.65	-0.03
TraditionalGroup $Mark_1$ vs. TraditionalGroup $Mark_2$	< 0.05	0.55
FlippedGroup $Mark_2$ vs. FlippedGroup $Mark_1$	< 0.04	1.06
FlippedGroup $Mark_2$ vs. TraditionalGroup $Mark_2$	< 0.03	0.74
FlippedGroup $Lab_{1,2}$ vs. TraditionalGroup $Lab_{1,2}$	< 0.03	0.63

5.2 Threats to Validity

Internal Validity. We filtered out students that could have studied the Object-Oriented paradigm or Java language attending a programming course at secondary school by using the "Initial Skill Assessment Test". Moreover, we did not inform students about the experimental hypothesis, and we did not reward for participation in the experiment.

External Validity. The obtained results lack generalizability at some points. Firstly, results are valid only in contexts similar to programming courses of computer science degrees. Even the representativeness of the materials used, all were academic exams, is not generalizable. We are also aware that different topics might have different complexity and, as a result, they could influence the results. Finally, since the sample is not representative of all populations of students (e.g., cohorts with different educational backgrounds, different programming languages), future experimentations are necessary.

Construct Validity. To mitigate the threat that the Flipped approach could be more motivating for students, we limit the usage of Flipped only to planned session in which all the students were involved. Another threat could be related to how we measure the accuracy of programming. We relied on solutions, previously defined by authors, to objectively evaluate whether the exceptions inserted in the source code were correct.

Conclusion Validity. The conclusions are founded on an adequate statistical method fulfilling all the requirements needed to be applied. We also obtained an acceptable statistical power thanks to the number of experimental subjects that was sufficiently large.

6 Concluding Remarks

In this paper, we presented a flipped strategy for laboratory sessions of a course focused on Object-Oriented paradigm, in a second-year programming university course. The approach was evaluated comparing the application of Object-Oriented concepts in a programming task between two students' groups, one trained by following a flipped approach while the other the traditional approach. Results demonstrate that the flipped approach has the potential to improve programming performances of students. In our future experiences, it would be interesting to collect more measures such as time spent to solve the task, the degree of satisfaction of students. These issues concern improved clarity, interest, usefulness, concreteness, simplicity, effectiveness, and perception of students to have learned the concepts of the task entrusted to them.

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Q&A Generation for Flashcards Within a Transformer-Based Framework

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Abstract. Flashcards are the main tool used in the Spaced Repetition memorization method, yet there are not always available for many topics due to the high effort required to create them. The combination of Transformer-based models with a Recommender System (RS) can enable a dynamic model to auto generate flashcards recommendation for learners and serious game players in order to improve their skills in learning programming. In previous work we introduced an Intelligent Serious Games (ISG) model that combined Deep Knowledge Tracing (DKT) with a Transformer-based Recommender. The ISG aimed at predicting the outcomes of the next missions in gameplay and enabling flashcard recommendations to complete the missions successfully. This research extends previous work by introducing a novel architecture and specifications for a Transformer-based recommender. We introduce a novel Transformer-based framework tailored to three different NLP tasks to dynamically generate flashcards in the form of supporting paragraphs, questions, and answers. We fine-tuned GPT-2, GPT-Neo, BART and T5 models on three new programming skills datasets, and evaluated them using standard metrics that target coherence and semantics. Our findings revealed that the framework is capable of generating coherent flashcards in a fully automated process using a single input string as prompt.

Keywords: Transformer · GPT-2 · BART · T5 · flashcards · question and answer generation · summarization · intelligent serious games · knowledge tracing

1 Introduction

The emergence of the Transformer-based language models [1] such as GPT-2 [2], BART [3] and T5 [4] caused a significant breakthrough in several NLP tasks. These models are already pre-trained on corpus of a huge number of text and have the capability of additional fine-tuning to particular knowledge domains. Transformer-based models have proven to be effective and outperform the other models in the NLP tasks [5, 6] such as text generation, questions/answers generation and summarization. These tasks can be deployed in different contexts such as for recommendations, feedback, and to generate flashcards.

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Flashcards are an effective and common tool for the spaced repetition technique. Whereas spaced repetition is an evidence-based learning technique that aims at reviewing the learning material at systematic intervals to form a long-term memory and improve information retrieval [7, 8]. Flashcards method is to label those with well-known concepts as less frequent review, while difficult or forgotten concepts are labeled with more frequent review to be shown frequently in spaced intervals.

Thabet and Zanichelli in a recent work [9] have introduced an Intelligent Serious Games (ISG) model based on combing Deep Knowledge Tracing (DKT) [10] with a Transformer-based Recommender. The main task of the ISG model is to look at one or more steps ahead in the gameplay to predict the outcome of the next missions with enabling proactive recommendations for players to complete the next missions successfully.

This paper introduces a novel architecture and specifications for the Transformer-based recommender [9]. We introduced a novel Transformer-based framework tailored with three NLP tasks to generate flashcards in a fully automated process.

The Transformer-based framework is based on the capabilities of recent language models, namely GPT-2/Neo, BART and T5, which were fine-tuned for the C++ programming domain using new specific datasets and generate the textual components of flashcards in the form of supporting paragraphs, questions, and answers. We also compared the performance of these language models by carrying out a thorough assessment of the coherence and semantics of generated and summarized text using standard metrics. The evaluation also examined the capability of the model trained on a subset of the C++ topics to generate questions for the rest of the topics and the influence of the dataset size on the question generation performance.

2 Related Work

Several tasks in the field of NLP are rapidly evolving such as text completion, summarization, question/answer generation. Traditionally deep learning has demonstrated its potential over NLP tasks based on the Recurrent Neural Networks (RNNs) [11]. However, processing long texts caused some limitations [12] due to the sequential processing that slows down the propagation speed in addition to the need of using parallel computing. This led to the emergence of the Transformer [1] based encoder-decoder architecture as a significant breakthrough in the NLP tasks. Different Transformer-based models were introduced such as BERT [13] as a masked model encoder, OpenAI GPT [14] as decoder and its successors GPT 2 [2] and GPT 3 [15] for business (GPT-Neo research version). These models were pre-trained on a large corpus and have the capability of additional fine-tuning to a specific domain. Several studies such as [12, 16–18] have fine-tunned these models on customized datasets in different domains to generate text. The authors in [17], investigated the efficacy of dialogue generation for in role-playing games. Other authors highlighted on some limitations related coherence and semantic of the generated text. However, in order to improve the generated text the authors in [12, 16–18] have transformed the plain text into semi-structured text by injecting the training dataset with metadata, special tags, and tokens to provide extra level of annotation to describe the text structure while training data.

In contrast, other models such as BART [3] and T5 [4] have been introduced as encoder-decoder models to perform conditional text generations. These models are sequence to sequence (seq2seq) which take a sentence as an input in the encoder and produce another output sentence from the decoder part. In practice, seq2seq models are capable to outperform the other models in some NLP tasks such as in summarization [19], question generation and translation [5]. Several studies have investigated the question/answer generation task. The authors in [20, 21] have proposed to generate questions from a given text, while the authors in [22] focused on generating answers for given questions. A recent study in [23] have proposed an automatic question-answer generation using ProphetNet [24] model to generate questions from a given text. The authors have filtered questions by computing the cosine similarity to exclude unanswerable and irrelevant questions, then they have generated answers for the non-excluded questions using BERT model.

However, a recent review study in [5] revealed that the majority of the questions generation studies have attempted to fine-tune BERT and GPT which are not appropriate for this task since they are designed for language understanding instead of language generating. The authors suggest using seq2seq models which are capable of modeling together context texts with different lengths, answers with different granularities, and questions with different types. Also, the authors suggest focusing on generating questions for the purpose of information seeking and recommendation. Also, Kurdi et al. in [25] have conducted a comprehensive systematic review to address questions generation for educational purposes. The review revealed that the majority of the studies have focused only on some areas such as generating questions in the language domain and for assessment purpose, whereas the template-based approach with pre- and post-processing tasks was mostly used.

3 Transformer-Based Recommender

3.1 Recommendation and Filtering Context

The Transformer-based recommender is context-aware [26, 27] with the DKT prediction result as the reaction time, and with a player's attempt to move to a new code challenge as the location. The main task of the recommender is to generate recommendations for a player in the form of flashcards as soon as the DKT prediction result is most probably "Fail" in the next mission. In addition to that, the recommender performs on each reaction a spaced repetition filtering to show all previous flashcards labeled with knowledge state "non-acquired" for a player. Indeed, this recommender reaction and filtering technique enable an evidence-based learning approach for players to form a long-term memory through spaced repetition practice and feedback-driven metacognition [7, 28]. In particular, each flashcard consists of a question and an answer to improve information retrieval of players followed by a supporting paragraph to be provided as feedback-driven for players "to know what they know and know what they don't know" [28].

3.2 Transformer-Based Recommender Architecture

As shown in Fig. 1, the architecture of the Transformer-based Recommender consists of the following:

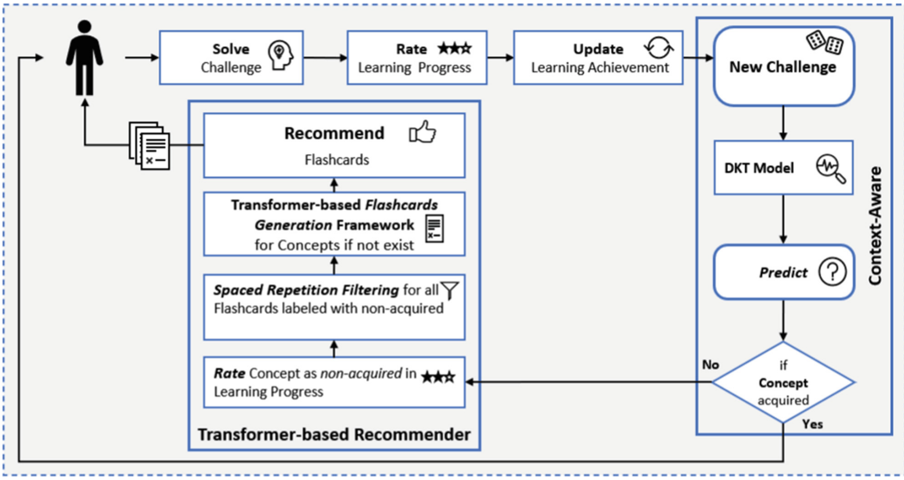

Fig. 1. Transformer-based Recommender Architecture and Overall Workflow

- Context-Aware component

  The overall process initiates when the player intends to move to the next new challenge, the DKT predicts the result of the next new challenge, and if the predicted result state is “acquired” the context-aware component allows the player to move and solve the challenge without recommendations. Otherwise, the context-aware component proceeds directly to the recommendation process before letting the player solve the challenge.
- Transformer-based Recommender

  Initiates by rating the predicted concept as non-acquired, applies spaced repetition filtering to retrieve all previous flashcards labeled with non-acquired, generates a flashcard for the predicted concept if it is not already generated from previous turns, and finally recommends and shows the new flashcard with all filtered ones for a player.

```
Output: Recommend_For_Player (Transformer_Flashcard_Generator (c_k))
Context_Aware_Code()
1   Concepts: [ c_1, c_2, ..c_i, ...c_t ...]
2   Next Challenge ← c_{i+1}
3   Result ←DKT_Predict ( vector, c_{i+1})
4   If Result is non-acquired, then
5     | Transformer_Recommender ( c_{i+1})
6   end
Transformer_Recommender ( c_{i+1})
7   Rate c_{i+1} ← non-acquired
8   foreach c_k in Concepts where k ≤ i + 1  // spaced repetition
9     If c_k is non-acquired then
10      | Recommend_For_Player (Transformer_Flashcard_Generator (c_k))
11    end
12  end
Transformer_Flashcard_Generator ( C_k)
13  FlashCards_Pool: [ F_1, F_2, .. F_{k-1}, ... F_t ...]
14  If F_k is not in FlashCards_Pool
15    | F_k ← Generate_Flashcard ( C_k)
16  end
17  Return F_k
```

Fig. 2. Transformer-based Recommender Algorithm

Figure 2 demonstrates the recommendation algorithm as follows:

1. Context_Aware_Code() method get invoked every time a player intends to move to a new code challenge.
2. At line 3 the DKT model predicts the next challenge ci + 1 and if the result is non-acquired at line 4, invoke the method Transformer_Recommender(ci + 1) at line 5.
3. Rate the predicted concept as non-acquired in the learning progress at line 7.
4. At lines 8 and 9 perform spaced-repetition filtering by retrieving each previous concept ck labeled with non-acquired.
5. At line 10 recommend for players a relevant flashcard for the newly predicted concept and each concept ck labeled with non-acquired by invoking the method Transformer_Flashcard_Generator(ck).
6. The method Transformer_Flashcard_Generator(ck) at line 14 performs a check if a relevant flashcard Fk is not already generated, then the method generates Fk flashcard at line 15 using the Transformer-based Flashcards Framework that we will introduce in the next suction.
7. At line 17 return Fk flashcard for the recommendation method at line 10.
8. Repeat line 8 (number 4 above) for each concept ck labeled with non-acquired.

3.3 Transformer-Based Flashcards Generation Framework

With reference to the recent findings and future directions that we discussed before; we introduce in this section a novel Transformer-based framework to generate flashcards in a fully automated process. The new framework combines several transformer-based models which are fine-tuned and tailored to three different NLP tasks of flashcards generation process as shown in Fig. 3:

1. **The Paragraph Generator:** this task receives an input string to generate a relevant paragraph using a fine-tuned GPT-2/Neo decoder, the output of this task is used as an input for task-2.
2. **The Answer Generator:** this task receives a paragraph as an input to generate a relevant answer using the BART/T5 seq2seq models that fine-tuned on the summarization task.
3. **The Question Generator:** this task receives an answer as an input to generate a relevant question using T5 seq2seq model fine-tuned on the task of questions generation.

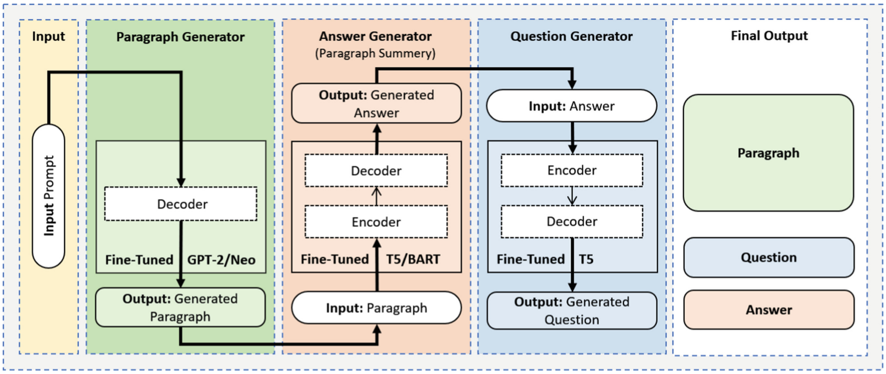

Fig. 3. A Framework for Fully Automated Flashcards Generation

This generic framework can be used in any context for generating paragraphs, answers, and questions. Moreover, the framework needs three different datasets relevant to the discipline to be fine-tuned on the generation tasks. In our research we introduced three C++ programming skills datasets to fine-tune the models on the context of C++ programming skills. Also, for implementing this framework, we recommend evaluating it using quantitative metrics to measure the N-gram overlaps between the generated and the reference text, and to measure the semantic similarity. We believe this is crucial to maintain coherence text and correct semantically.

4 Experiments and Results

4.1 Datasets

Dataset1: C++ Code Guide (C++ CG)

For paragraph generation task, we collected data from some free C++ programming skills tutorial websites by a web scraping tool developed in Python. We cleaned the dataset and transformed 2300 of text lines into proper statements and paragraphs with tags structure such as: < |title|> to indicate starting a new concept; < |define|> for concepts' definition; < |explain|> for more description; < |code|> to indicate starting a code example followed by < |endoftitle|>.

1 https://www.kaggle.com/datasets/
2 http://www.cs.cmu.edu/~glai1/data/race/
3 https://stanfordnlp.github.io/coqa/
4 https://rajpurkar.github.io/SQuAD-explorer/
5 https://allenai.org/data/sciq/

Dataset2: C++ Summaries (C++ SUMM)
For answer generation task, unluckily, we were not able to find any public datasets relevant to C++ summaries. Accordingly, we collected C++ paragraphs from different C++ websites, and we manually provided a summary for each paragraph to form a dataset with 300 C++ paragraphs/summaries covering different topics in C++. Also, in order to train the model to recognize other forms of summarization, we added to the dataset 3700 paragraphs/summaries from the standard dataset cnn_dailymail[1] to produce a C++ Summary dataset with 4000 pairs of paragraphs/summaries.

Dataset3: C++ Questions/Answers (C++ QA)
For questions generation task, the majority of the available question/answer datasets that we found was related to other topics such as RACE[2] for English language, CoQA[3] conversational-style QA dataset, Wikipedia-based Stanford QA Dataset SQuAD[4], and SciQ[5] for multi-disciplines in science exams. Initially, we searched the web and collected 500 pairs of questions/answers covering 28 topics in C++. Also, in order to train the model to recognize other forms of questions, we added to the dataset 1500 Q/A from the datasets RACE, CoQA and SQuAD, and 1000 from SciQ dataset to produce a C++ QA dataset with 3000 pairs of question/answer.

4.2 Evaluation Metrics

For all the experiments we considered three metrics: SacreBLEU [29] which is a recent variant of BLEU [30]; ROUGE [31]; and SBERT Sentence Transformers [32]. SacreBLEU and ROUGE are the common metrics in the text generation problem and rely on N-gram overlap. Rouge metric focuses on recall, while SacreBLEU focuses more on precision score. However, SBERT is a recent Transformer-based metric introduced to compute the cosine semantic similarity scores for all possible pairs between two sentence embeddings. Additionally, we consider computing the summary improvement ratio as the number of words between the paragraph and the answer summary. *Summary Improvement Ratio (P, S)* = |*P-S*| / |*P*|.

4.3 Results

Transformer-Based Paragraph Generation
We fine-tuned GPT-2/124M and GPT-Neo/125M on our C++ CG dataset to generate C++

paragraphs using Google Colab. We set the parameters temperature = 0.9 and top_p = 0.9. We investigated the models on three testing sets with generating 25 programming skills paragraphs for each. Set-1 to generate short definitions with max length = 50 words and using the prefix < |define|>, set-2 to complete sentences with max length 24 words and set-3 to generate long paragraphs and code example with max length 300 words using the prefix < |title|>.

The results in Table 1 show that the models are capable of generating programming skills text with scores higher than 85% for n-gram-based metrics and 90% for the semantic score. The high scores for both N-gram-based metrics and the cosine semantic confirmed that the models-maintained two important factors coherence and meaning of the generated paragraphs. However, limited BLEU scores are obtained on both models, but these results are expected as the BLEU score is a result of computing the geometric mean of all four N-gram precision scores, and the precision decreases when N increases. In the testing sets level, the long paragraphs (set-3) achieved the best semantic similarity score higher than 0.95 on both models followed by the short definitions (set-1), and complete sentences (set-2) was the last which were generated without prefix tags. This result confirms two conclusions: firstly, the models achieve better performance when associating prefix tags with the input prompt; secondly, increasing the max-length-size of the generated text has positively influenced the performance, as we assigned it to 300, 50 and 24 for long paragraphs, short definitions, and complete sentences respectively. Overall, GPT-Neo achieved slightly better performance than GPT-2 in definitions and paragraphs, whereas GPT-2 performed better than GPT-Neo only on the complete sentences with small max-length-size. Whereas changing the parameters temperature and top_p produces different and rephrased paragraphs which is helpful in increasing the reading comprehension for learners and players [33, 34].

Table 1. Models Performance

Model	Testing Set	SacreBLEU		ROUGE-1			SBERT
		Precision	BLEU Score	Precision	Recall	F1	Semantic Similarity
GPT-2	Set-1	0.808	0.760	0.838	0.887	0.843	0.937
	Set-2	0.918	0.807	0.933	0.846	0.880	0.930
	Set-3	0.901	0.750	0.901	0.875	0.876	0.959
GPT-Neo	Set-1	0.808	0.769	0.851	0.901	0.847	0.944
	Set-2	0.795	0.685	0.800	0.756	0.771	0.860
	Set-3	0.922	0.849	0.875	0.828	0.843	0.965

Transformer-Based Answer Generation

We fine-tuned T5-large and BART-large on our C++ SUMM dataset to generate C++ answers by summarizing given paragraphs using Google Colab. We set the parameters for training max_seq_length: 128, train_batch_size: 8 and 9 epochs, while for generations max_length: 50, top_k: 50, top_p: 0.95 and num_return_sequences to 1.

We conducted in total 18 experiments to generate answers by summarizing the generated paragraphs (C++ guide text) in the previous experiments. (1) we investigated and compared the performance of the models T5 and BART to generate C++ answers; (2) we examined the capability and the performance of the models trained on: (a) both cnn_dailymail and C++ summaries together; (b) C++ summaries only; (c) cnn_dailymail summaries only; to generate C++ answers. For this purpose, we produced 3 different versions of the C++ SUMM training dataset DS1, DS2 and DS3; (3) we investigated the influence of enabling/disabling the beam search and the greedy search decoding during the answer generation process; (4) we compared different performance metrics of the generated answers with respect to the summarization ratio.

Table 2. Average performance of generated answers

Dataset/ Model	Search Algorithm	ROUGE-1 P / R / F1	ROUGE-2 P / R / F1	ROUGE-L P / R / F1	Cosine Semantic Similarity Score	Summary Improv. Ratio %
DS1: BART	Sampling	0.603 /0.702 /0.624	0.603 /0.702 /0.624	0.603 /0.702 /0.624	0.869	44.0
	Beam	0.613 /0.709 /**0.634**	0.613 /0.709 /**0.634**	0.613 /0.709 /**0.634**	**0.873**	**44.5**
	Greedy	0.604 /0.694 /0.622	0.604 /0.694 /0.622	0.604 /0.694 /0.622	0.869	46.2
DS1: T5	Sampling	0.595 /0.577 /0.558	0.595 /0.577 /0.558	0.595 /0.577 /0.558	0.832	57.0
	Beam	0.616 /0.595 /0.575	0.616 /0.595 /0.575	0.616 /0.595 /0.575	**0.850**	**57.4**
	Greedy	0.6 /0.587 /0.564	0.6 /0.587 /0.564	0.6 /0.587 /0.564	0.847	57.2
DS2: BART	Sampling	0.571 /0.678 /0.595	0.571 /0.678 /0.595	0.571 /0.678 /0.595	0.856	43.6
	Beam	0.575 /0.681 /0.596	0.575 /0.681 /0.596	0.575 /0.681 /0.596	0.856	43.3
	Greedy	0.596 /0.695 /0.622	0.596 /0.695 /0.622	0.596 /0.695 /0.622	0.870	44.8
DS2: T5	Sampling	0.509 /0.517 /0.485	0.509 /0.517 /0.485	0.509 /0.517 /0.485	0.792	53.4
	Beam	0.497 /0.516 /0.482	0.497 /0.516 /0.482	0.497 /0.516 /0.482	0.805	53.1

(*continued*)

Table 2. (*continued*)

Dataset/ Model	Search Algorithm	ROUGE-1 P / R / F1	ROUGE-2 P / R / F1	ROUGE-L P / R / F1	Cosine Semantic Similarity Score	Summary Improv. Ratio %
	Greedy	0.485 /0.481 /0.456	0.485 /0.481 /0.456	0.485 /0.481 /0.456	0.797	56.4
DS3: BART	Sampling	0.411 /0.76 /0.515	0.411 /0.76 /0.515	0.411 /0.76 /0.515	0.824	16.1
	Beam	0.41 /0.763 /0.514	0.41 /0.763 /0.514	0.41 /0.763 /0.514	0.827	15.4
	Greedy	0.437 /0.782 /0.543	0.437 /0.782 /0.543	0.437 /0.782 /0.543	0.837	17.7
DS3: T5	Sampling	0.353 /0.618 /0.433	0.353 /0.618 /0.433	0.353 /0.618 /0.433	0.773	21.7
	Beam	0.365 /0.641 /0.448	0.365 /0.641 /0.448	0.365 /0.641 /0.448	0.791	21.1
	Greedy	0.366 /0.642 /0.45	0.366 /0.642 /0.45	0.366 /0.642 /0.45	0.793	21.0

We repeated each experiment 10 times and we computed the average performance for each metric. Results in Table 2 show that the models are capable to summarize paragraphs and generate C++ answers even with a trained dataset that consists of only C++ summaries in DS1. Whereas DS2 with mixed C++ and cnn-dailymail summaries for the BART model and beam search achieved the best average of F1 scores for all Rouge metrics and cosine semantic similarity score of 0.873 with summarization ratio reached to 44.5%. This is a slight improvement over when enable sampling or greedy search instead of beam on the same model. Also, slightly performance decrease was obtained on the BART model when using the C++ summaries only in the training dataset with scores 0.856 for both beam and sampling, and 0.870 when enabling the greedy search. However, generating answers by training a dataset that consists of the cnn-dailymail summaries only showed decreasing in the cosine similarity scores under 0.840 and a significant decreasing in the summarization ratio to less than 22%, which means that the models just re-generating almost the same paragraphs.

In general, BART model achieved best Rouge and Cosine semantic similarity scores on all datasets, while T5 achieved best summarization ratio with 24% increase over the BART model as shown in Fig. 4. For the model's generator decoding methods, Fig. 5 shows that beam decoding mostly demonstrated better scores than the others, whereas greedy search decoding comes next, and random sampling in the last. Despite the greedy came as the second in the quantitative scores, but in reality, the greedy search returns the most probable next word, which means it mostly returns the same sentences without rephrasing new sentences, as we conducted a qualitative evaluation and the result comes to confirm.

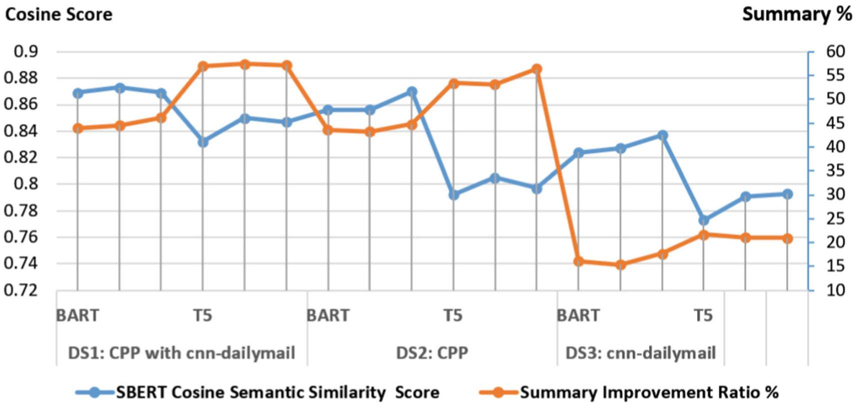

Fig. 4. Average Cosine Semantic Similarity Scores and Summary Ratio

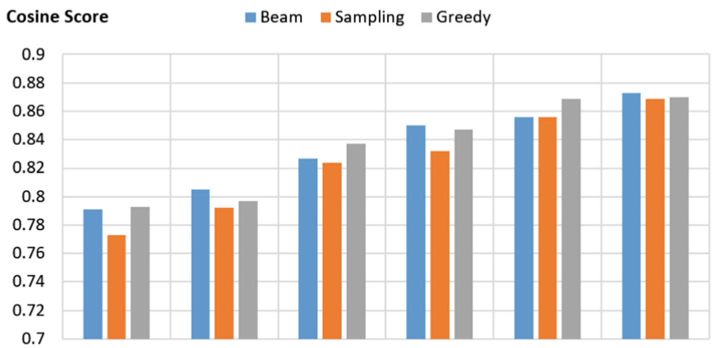

Fig. 5. Average Cosine Semantic Similarity Scores for search algorithms

In summary, we fined-tuned the BART and T5 models with a new C++ Summary dataset (C++ SUMM) to summarize and generate answers from the generated paragraphs in the previous experiments. The results revealed that the models are capable to summarize paragraphs and generate C++ answers with best semantic similarity score 0.873 and best summarization ratio reached to 57.4%. Also, combining C++ and cnn-dailymail summaries together achieved better scores on all metrics, whereas, using a dataset with irrelevant summaries alone downgraded the performance. Using the summarization ratio uncovers the importance of using this metric in the summarization task. Despite the models in some cases achieves accepted scores, but in reality, it is regenerating almost the same paragraphs. Overall, BART model demonstrated better Rouge and Cosine Semantic scores, whereas T5 model showed better summarization ratio. Finally, the quantitative scores revealed that the beam decoding obtained the best performance followed by the greedy search decoding. Whereas the qualitative evaluation uncover that the beam and the sampling decoding methods are better than the greedy as the latter mostly returns same sentences without rephrasing new sentences.

Transformer-Based Question Generation

We fine-tuned T5-large on our C++ QA and on SciQ datasets to generate C++ generate questions from given answers using Google Colab. we set the parameters for training max_seq_length: 128, train_batch_size: 8 and 6 epochs, while for generations num_beams: None, do_sample: True, max_length: 50, top_k: 50, top_p: 0.95 and num_return_sequences to 1.

(1) Exp. Set-1: We examined the capability of the model trained on a subset of the topics to generate questions for the rest of the topics. Among of 28 C++ topics, we conducted 6 experiments using 6 different versions of the C++ QA training dataset to include 0 topics (i.e., only the SciQ dataset was used), 4 topics, 7 topics, 14 topics, 21 topics and 28 topics. For each 60 questions used for testing. (2) Exp. Set-2: We investigated the influence of the dataset size on the performance of the generated questions, we tested on 25%, 50% and 75% of 440 C++ Question/Answers, while the remaining 60 questions used for testing. (3) Exp. Set-3: As we were able to have at most only 440 C++ questions available for training, in order to investigate the influence of the dataset size on the performance we had to resort to science questions from the larger SciQ dataset. We started with 440 questions and scaled up to tenfold in ten experiments. We repeated each experiment 10 times and we computed the average performance for each metric as shown in Table 3. The variance is not reported as it was less than 0.001 for all experiments.

Results in Table 3 show that the fine-tuned model is capable of generating C++ questions even when only 15% of the topics are covered in the training data. The model achieved best cosine semantic similarity score of 0.868 when all the topics are included in the training dataset, with a slight 1% improvement over when including 75% of the topics (score 0.859). Limited performance decrease was obtained when covering 50% and 25% of the topics with scores 0.838 and 0.789 respectively. However, decreasing under 25% the included topics in the training datasets produced similarity cosine scores of 0.768 and 0.563 for 15% and 0% of the topics, respectively. For the other metrics, results show oscillating scores between 0.5 and 0.7 and this is due to the model rephrasing questions semantically correct but using different words or phrases.

For the second experiment set (lower part of Table 3), results evidenced that performance slightly decreases when decreasing the number of C++ questions (all randomly chosen from the available 440 C++ QA questions) in the training dataset. For instance, the similarity score decreased to 0.855 when using 75% of the questions, whereas the scores decreased to 0.837 and 0.810 when using 50% and 25% of the available C++ QA 440 questions for training, respectively. We examined the effect of increasing the dataset size using the SciQ dataset in which we have enough questions to test up to tenfold.

Table 3. C++ Questions Generation Performance

Exp.Set-1: Percentage of CPP Topics in the Training DS		Sacre BLEU	ROUGE-1			Cosine Semantic Similarity
		P	P	R	F1	
1	0% of Topics	0.205	0.199	0.430	0.251	0.563
2	15% of Topics	0.503	0.579	0.670	0.595	0.768
3	25% of Topics	0.48	0.582	0.649	0.576	0.789
4	50% of Topics	0.597	0.659	0.648	0.631	0.838
5	75% of Topics	0.702	0.705	0.667	0.666	0.859
6	100% of Topics and Questions	0.729	0.743	0.763	0.739	0.868
Exp.Set-2: Percentage of the 440 C++ Questions in the Training DS						
1	75% of Questions	0.757	0.751	0.751	0.734	0.855
2	50% of Questions	0.693	0.729	0.735	0.712	0.837
3	25% of Questions	0.617	0.669	0.672	0.646	0.81

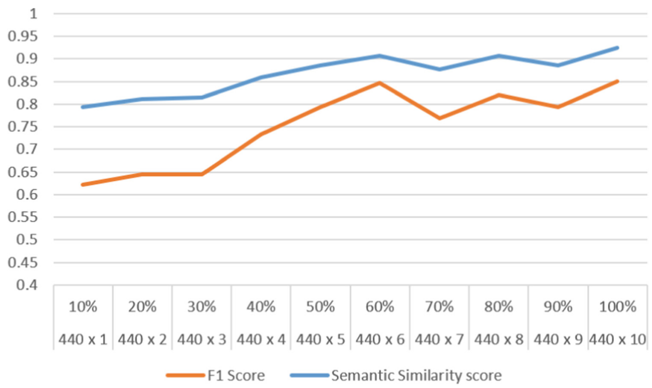

Fig. 6. Performance Trend of Science Questions Generation

For the experiment set 3 as shown in Fig. 6, results confirmed that the model achieves some performance improvements when increasing the number of SciQ questions in the training dataset. For instance, the generated questions at 10X outperformed the others with similarity score 0.924 whereas at 5X and 1X achieved 0.885 and 0.794 similarity scores respectively. To compare both datasets, results hint that increasing the C++ dataset may improve the performance of the generated questions. However, the science questions needed 4X to 5X of the data to achieve the same 0.868 SBERT semantic similarity score of C++ questions. This is expected due to fact the C++ topics are limited in number, while the science question dataset is much more general as it covers chemistry, biology, physics, and other disciplines, thus it needs more training questions to learn from.

In summary, we fined-tuned T5 model with a new dataset to generate C++ questions for the flashcards. We evaluated the model by two N-gram-based metrics and a cosine semantic similarity metric. The results revealed that the fine-tuned model is capable of generating coherent questions with a semantic similarity score around 0.87. Also, we investigated the performance of the model to generate C++ questions for topics not included in the training dataset, the results revealed that the model is able to generate coherent questions with including only 15% of the topics in the training data. Furthermore, we investigated the influence of the dataset size on the performance of the generated C++ questions and on the science questions dataset, the results for both datasets show that increasing the number of relevant questions in the training data can improve the performance of the generated questions. Finally, we remark we also explored the ability of generating C++ questions using a training dataset with only science questions (row 1 in Table 3). Results revealed that the model can generate only up to 50% coherent questions, while the other 50% is incorrect/irrelevant. These results underline the importance of having a relevant Q&A dataset so that the model can recognize the context and the terms' dependencies for a certain subject.

Table 4. Flashcards generation examples

Input Prompt	Generated Paragraph	Generated Answer	Generated Question
<|title|> scope	*Scope refers to the area of code where a variable can be accessed, while lifetime refers to the duration of time for which a variable exists. In older programming languages, scope and lifetime are usually the same, but in newer languages like C++ they have different meanings, it is possible for a variable to be out of scope but still alive, which is exploited in the creation of classes*	*Scope and lifetime have different meanings. Scope is where a variable can be accessed, but lifetime is how long a variable exists*	*What is the difference between variable scope and lifetime?*

(*continued*)

Table 4. (*continued*)

<table>
<tr><th>Input Prompt</th><th>Generated Paragraph</th><th>Generated Answer</th><th>Generated Question</th></tr>
<tr><td>< |title|> conversion</td><td>Type conversion is changing an entity of one data type into another. This is done to take advantage of certain features of type hierarchies, or to enable operations that were not previously possible. Type conversion can lead to loss of data if it is not done carefully</td><td>Type conversion is changing one data type into another. This can lead to loss of data if it is not done carefully</td><td>What is the type conversion?</td></tr>
<tr><td>< |Define|> conditional statement</td><td>A conditional is a statement that tells the computer to control the flow of a program based on whether a certain condition is met. The most common conditional is the if-else statement, but there are also conditional expressions and switch-case statements</td><td>A conditional is a statement that allows you to control the flow of your program based on whether a condition is true or false</td><td>What is a conditional statement?</td></tr>
</table>

5 Conclusions and Future Work

In this work, we presented a novel architecture and specifications of the Transformer-based recommender for the ISG model. We introduced a novel Transformer-based Recommender architecture to generate recommendations in programming skills. We introduced and evaluated a novel Transformer-based framework tailored with three NLP tasks to generate flashcards in a fully automated process. Using three new programming skills datasets, we fined-tuned GPT-2, GPT-Neo, BART and T5 models to three different NLP tasks to generate paragraphs, questions, and answers (see Table 4). We also considered three metrics to evaluate the N-gram overlaps and the semantic similarity to assure the quality and capability of the models. Through three experiment sets, the results revealed that Transformer-based framework with fine-tuned models is capable to generate coherent flashcards as paragraphs, questions, answers, and code examples for programming skills.

The transformer-based generators provide specifications to allow the adaptation in different contexts and disciplines for learning and gaming. This work focused on assessing and evaluating the efficacy and the feasibility of the Transformer-based Framework flashcards generator. Further work will address the influence and the effectiveness of Transformer-Based Recommender architecture to generalize the recommendation model. Other future opportunities to extend this work also includes a scoring task so that the model will be capable to evaluate short answers given by learners/players. In addition to investigating the ability of the model to generate multiple questions/answers from a certain paragraph.

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