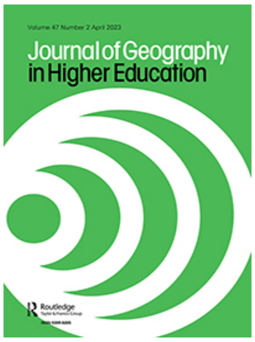


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# Student evaluations of using virtual reality to investigate natural hazard field sites

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**ABSTRACT**
At a time when traditional fieldwork is coming under pressure, be it from shrinking budgets, reducing carbon footprints, increased concerns for personal safety or the desire to make field skills accessible to all, how do we ensure that the key skills of observation, data collection and landscape analysis can still be developed in our students? This paper evaluates the experiences of students using immersive virtual reality (VR) to interrogate highly accurate georeferenced landscape models, made from data collected by Unmanned Aerial Vehicles, through the medium of Q methodology. It finds that there appears to be an association between prior engagement and expertise with IT and gaming technologies, such that those who declare some degree of prowess engage with and embrace the opportunities of using VR. This suggests that to allow more students to adopt positive approaches to learning in this manner, educators need to worry less about ever complex and realistic models, and invest more into positive prior experiences of using technology. Moreover, an important voice in the narrative around the physical nature of "being in the field" and social interaction with peers and tutors questions an approach that is still a relatively solitary experience.

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VR; fieldwork; UAV; presage; learning approaches; Q methodology

## Introduction

"The implication of this research is quite clear . . ..fieldwork is indeed good"

(Boyle et al., 2007)

The role of fieldwork in our disciplines is widely regarded as integral, some claiming it to be a "signature pedagogy" (Seow et al., 2019); a teaching and learning practice that is both common and defines the discipline (Shulman, 2005). This has led to an extensive effort to examine the learning approaches by students and effectiveness of fieldwork in a variety of guises. This paper addresses student evaluations of one

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such approach that was devised to create solutions to present-day issues in addressing and organising fieldwork. The approach taken to this evaluation shows that the development of relatively novel approaches to these thorny issues should start with one of the key ideas of any teaching practice; the preparedness of students to embrace such interventions, which might be ignored due to assumptions around levels of digital literacy (Bennett & Maton, 2010).

There is a demand for highly skilled professionals in the environmental and geoscience sectors, who can be innovative, creative and show particular skills in advanced 3D spatial analysis, multidisciplinarity, data management and informatics, mathematical and numerical skills, fieldwork and observations skills, earth observation and image analysis. Typically, this has been taught through a mix of field visits, observations and data collection, allied to desk-based analysis of maps and other field and satellite-derived data products, most often through the use of maps and, latterly, GIS. There is also a disconnect between the understanding of geomorphological setting and geohazards in the onshore and offshore environments. With increasing expansion of development in offshore and marginal onshore environments, there is an increasing demand for experts able to recognise and assess geohazards and associated risks, as a consequence of population increase, infrastructure development and climate change.

However, the traditional view of the field scientist as the roving explorer, visiting new and exciting places, has to be positioned against curricula that often teach environmental responsibility and decarbonisation. Most geoscience curricula now acknowledge the reality of human-induced climate change (Hopkins et al., 2019; Welsh & France, 2012), of which global travel is a significant contributor (Higham & Font, 2020). Whilst not alleviating a global problem, many students, and their institutions, wish to be seen to be playing their part by reducing their own carbon footprints.

Higher education is also required to consider its wider accessibility. Field trips can be seen as a barrier for many students, either financially or due to a range of personal health issues that mean that engaging with fieldwork requires real innovation by institutions (Mol & Atchison, 2019). There is a need to rethink fieldwork operations so that all can benefit from the intellectual skills developed by interrogating landscape.

Finally, institutions need, more than ever, perhaps, to consider the risk involved in fieldwork. This may be financial risk, where budgets are stretched to allow our traditional diets of field trips to continue (Wilson et al., 2017), or these might be real risks to health and wellbeing by working in hazardous or personally challenging environments (Tucker & Horton, 2019). The study of geohazards, by implication, might require students to work in environments that are potentially riskier than others, and in a world where adversity to risk is becoming more important, alternatives to students clambering over the land might be seen as preferred.

The role of the "virtual field trip" has been debated for some time now, and much has been made of a range of interventions (Cliffe, 2017). These are often a mix of paper and web-based resources that allow students to "see" the field site and use observational skills, and then either interrogate another set of photographic data for deriving measurements (by using field technologies that allow high-resolution photo montages to be derived) or maps and previously collected data to analyse the kinds of measurements that geologists make in the field, so called "non-immersive" virtual reality (Radianti et al., 2020). However, these interventions all seem to have the same issue, which is how students match data to location, and small to large scales. In a skill set that some students already find challenging to master, these are yet two more areas of cognition that they will have to develop through the use of virtual field trips, two that are actually much easier to grasp when situated in the real world.

The ERASMUS funded 3DTeLC project (www.3dtelc.com) discussed in this study created 3D models which are accurately georeferenced, and are internally accurate to such a degree that the kinds of field measurements that geologists often make can be faithfully recreated for further manipulation through GIS (Tibaldi et al., 2020). It focused on the use and integration of terrestrial remotely piloted airborne systems imagery and submarine remotely operated vehicle data for the combined study of geohazards in terrestrial and marine environments. Taking this data, it developed these 3D models within commonly used gaming software so that students could move around and interrogate these models in virtual reality (VR) using readily available VR headsets and controllers, developing so-called "immersive" VR experiences (Radianti et al., 2020). Using data from a range of geological settings such as landslides (e.g. The Chale Terraces, UK), tectonics (e.g. Husavik, Iceland) and submarine settings (offshore Santorini, Southern Aegean Sea), students can explore the whole field site and make decisions about what data they wish to collect and where. The larger area models that remote vehicles can collect for enables students to see a "bigger picture" placing their small section of geology in relation to a wider landscape.

Fowler (2015) has argued for the potential learning benefits from the use of 3D virtual learning environments, but suggested that much of what has been written has been of a largely "show and tell" nature. Radianti et al. (2020) concluded that there was a gap in considering how students approach their learning with VR, and a focus on usability over pedagogy.

In geoscience classrooms, these characteristics of educational work with immersive VR are still very much present. Qualitatively, students report that immersive VR fosters a better understanding of location, and the interaction of the various elements within a landscape, and is an intellectually challenging experience (Philips et al., 2015). Students acknowledged that the use of the high-end technology was appealing, fascinating, and fun, such that they felt engaged and their learning enhanced (Detyna & Kadiri, 2020; Philips et al., 2015). Many of these perceived learning gains are attributed to the issue of "presence" or "being there", which immersive VR is argued to give (Detyna & Kadiri, 2020). This is due to the high levels of fidelity of representation and the ability of students to manage their own exploration of a landscape (Dalgarno & Lee, 2010).

Practically, immersive VR environments in geoscience classrooms have been shown to increase time on task, yet yield less accurate task completion (Juřík et al., 2020). It has been argued that this is potentially due to the large amount of information that needed to be processed when encountering the 3D model, but that the accuracy with which these tasks were completed was lower.

In general, however, the use of immersive VR in geoscience is less well documented than other digital applications that are more compatible with lower-end, more accessible technologies such as the use of mobile devices for collecting and analysing field data (e.g. I. C. Fuller & France, 2016; I. Fuller & France, 2014), or producing augmented reality experiences (e.g. Priestnall et al., 2019; Turan et al., 2018). The previously discussed advantages of immersive 3D experiences are somewhat negated, however, by these approaches as location in the field is essential in many, if not all, of these cases.

## Methodology

The study employed Q methodology to try and understand student perceptions of using VR to mimic traditional field surveys. Q methodology seeks to understand the complicated, and often overlapping, subjective views of participants (Wright, 2013). It does this through participants sorting an array of statements in accordance with a condition (say "Strongly agree" to "Strongly disagree"), but also ranking these statements relative to each other along this spectrum. The collective analysis of all individual participants' sorting data is done using a suitable variable reduction technique. Thus, the sort focuses upon the personal constructs and subjective values of participants rather than their performance in "objective" tests. Therefore, in Q, the subjects themselves become less important (as in more traditional, so-called, "R analysis"); it is their relative subjective views on a question that is of interest.

Q follows a series of relatively distinct phases, arriving at a set of factors that are judged to represent a variety of participant viewpoints. These methodological phases are the development of the concourse (a "universal" set of statements based upon the question under study), a refinement of the concourse into a set of statements for survey use (called the Q sample), identification of participants (called the P set, and here drawn from student volunteers), sorting of the Q set by participants, data analysis, and interpretation of factor solutions (Pike et al., 2015).

### *Concourse development*

The concourse is a collection of statements that encompass all views about the subject under scrutiny. As such the concourse is large, and the provenance of the statements can come from all walks of life; scholarly articles, blogs, face-to-face interviews, direct questions, personal opinion. One source of opinion was collected through engaging past ERASMUS summer school students. A simple, anonymous, Google Form was developed asking them to remember their VR experiences and identify a number of ways in which they think those exercises benefited (or not) their learning. Further statements within the concourse were collected through engaging with literature within the field of using VR in education, adapting the context of the statement to the virtual field exercise that was being undertaken.

Statements were then sorted and thematically grouped. Repetitive statements were removed, and confusing statements reworded for clarity. It was ensured that statements expressed one view in particular, so that participants did not feel that accepting a statement was conditional upon more than one value judgment. Drawing upon the work of Dalgarno and Lee (2010) and Fowler (2015), statements that explored themes of representational fidelity (a realistic display of the landscape, smooth transitions in view and motion, and the representation of the user) and learner interaction (embodied action, embodied verbal and non-verbal communication, and the control of various environmental and behavioural attributes) were finalised, arriving at a statement set (called the "Q sample") of 32 statements.

### The participant set

The 20 survey participants (or P-set) were taking part in the summer school run as part of the wider 3DTeLC project. They came from the four main partner institutions, and, whilst English was the common language of communication during this event, the statements were kept as clear and unambiguous as possible for ESL students. All 20 participants in the Summer School agreed to participate in the survey. All students were given the right to withdraw by non-completion of the survey, all survey results were anonymised by the software, such that there was no indication of which students had submitted which response.

### Distribution of the Q sample, and the Q sort

Participants then undertook an exercise designed to measure and map features of one of landscapes previously captured by UAV and modelled in 3D, the Chale Terraces on the south coast of the Isle of Wight, UK. After completing the tasks, they were guided to undertake the Q sort process which was accessed *via* a web browser, utilising the open-source HTMLQ software (Aproxima, 2015). Participants were asked to consider the statements against a condition of instruction which asked them to reflect upon their experience and assess to what extent they agreed or not with the statement in hand.

The statements were then sorted onto a grid with a quasi-normal distribution, with the distribution ranging from two poles representing points of most agreement or "most agree" to "most disagree", with each position along this spectrum given a score. This grid is shown in Figure 1. This technique allows some duplication in choice, but prevents the casual sorter from regarding everything as, say, "neutral" or "most important". The issue here is to force sorters to make a value judgment of one statement over another, not only along a spectrum of response, but also in relation to each statement within the Q set.

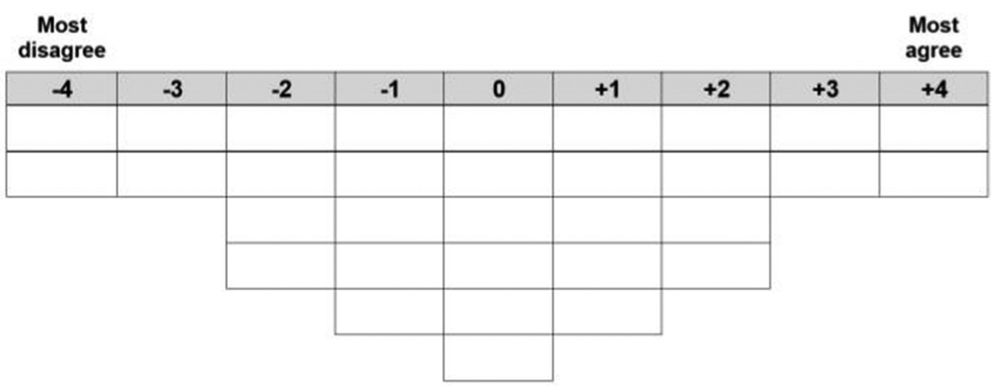


Figure 1. Sorting grid developed for this study.

Participants were also asked to briefly summarise their arguments as to why they had chosen the two statements at each pole of this distribution. They were then asked questions about their experience with all matters IT, and their familiarity with the gaming environment in particular. If they wished, participants could declare their gender, in case evaluations reflected experience and confidence levels that have been seen to be gender related (e.g. Leonhardt and Overå, 2021). Chi-squared analysis of this small data set showed no significant difference ($p < 0.05$) in confidence or experience scores amongst students who declared themselves to be male or female. All these data were stored, alongside their sort data, and collected anonymously.

### *Analysis*

The data were captured via a database, which was downloaded and processed by the freely available Ken-Q Analysis (v1.0.6) software developed by Banasick (2019). Analysis of the entire data set was undertaken using exploratory factor analysis. As this has long been privileged over allied techniques, such as PCA (Watts & Stenner, 2014). This analysis resulted in a small of factors that represent common patterns found within the sorting of statements by the participants. The degree to which these factors are associated with each participant's holistic opinion (as made manifest in their sort), is indicated by the factor loading. Finally, a final composite Q sort (or a factor array) represents each factor. This shows how each statement would have been scored purely under that factor. The results of the initial analysis, and the selection and rotation of factors is highlighted in the following "Results" section.

## Results

### *Self-Declared IT capability and familiarity data*

Students were asked to identify their gender (if they wished to) and their all-round confidence with IT and experience, particularly with gaming. The data can be seen in Table 1.

The loadings for the initial, unrotated, solution indicated that three factors should be kept, representing some 51% of total variance. The position of these sorts in Factor 1–2 factor space are illustrated in Figure 2. It was noted that three key sorts (Participant sorts 3, 5, and 9) sat at one extremity of this distribution, three participants who identified themselves as highly confident with IT with regular gaming experience. These sorts were taken to denote "self-declared expert" status.

Table 1. Results from participant declarations about confidence with IT and prior experience of gaming.

| Question | Self-declared rating | Male | Female |
|---|---|---|---|
| Confidence with IT | Not very confident | 0 | 1 |
| | I feel OK with IT | 1 | 4 |
| | I am quite confident using IT | 3 | 6 |
| | I am highly confident with IT | 3 | 2 |
| Experience with gaming technologies | I do not game at all | 1 | 6 |
| | I have a little experience with gaming | 1 | 3 |
| | I have some gaming experience; I play occasionally | 1 | 3 |
| | I am very experienced, and game very regularly | 4 | 1 |

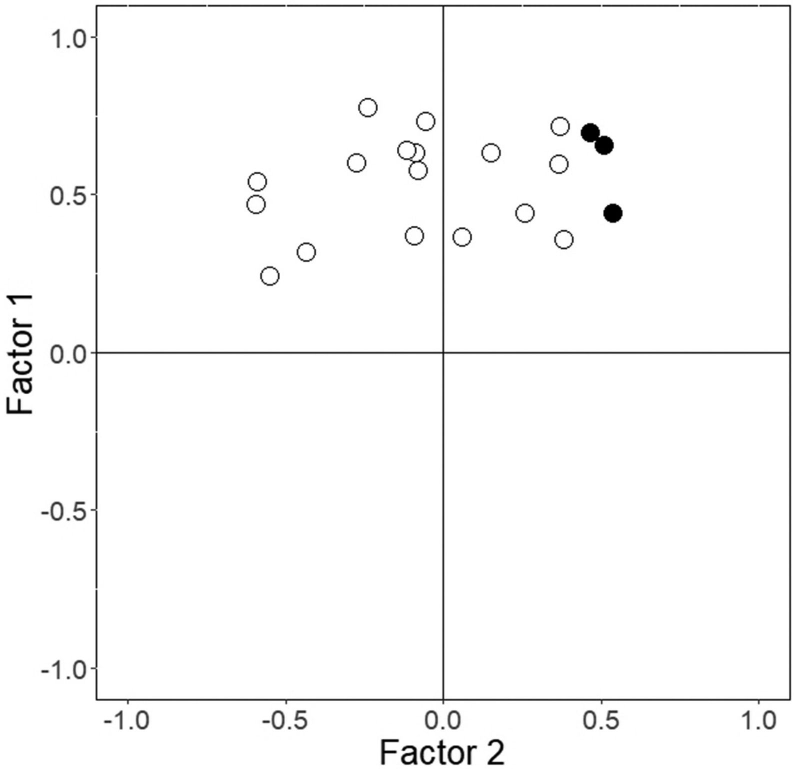


Figure 2. Loadings to Factors 1 and 2, with sorts 5, 4, and 9 (the 'self-declared experts) denoted by filled circles.

Following this identification of "self-declared expert" status, the factor solution was rotated, manually, through 40°, and Factor 2 inverted, so as to place maximum focus upon these key sorts, and view the subjective view of the participants with reference to this so-called "expert" group. The final, rotated, solution can be seen in Table 2, and represents 51% of the total variance, with 19 out of 20 sorts significantly loading ($p < 0.05$) to these factors. Table 2 illustrates that students can concurrently hold these three viewpoints (or Factors), as made manifest by their original sort and its analysis, yet often one of these viewpoints predominates; or "significantly loads" to a Factor.

The new position of these sorts in Factor 1–2 factor space are shown in Figure 3. Two large clusters of sorts emerged from this solution, focussed upon Factors 1 and 2, with one loading to Factor 4. The self-declared "experts" load to Factor 1, explaining 25% of the study variance, and sort numbers 3, 4, 5, 9, 10,12, 13, 14, and 16 significantly load to this factor. Factor 2 explains 19% of the study variance, and sort numbers 2, 6, 7, 11, 15, 17, 18, 19, and 20 significantly load. Finally, Factor 4 explains 7% of the total study variance and only sort number 8 significantly loads to this factor. These are represented in factor 1–2 space in Figure 3. The factor array scores are idealised sorts representing the distribution of statements against the sorting grid for each factor, and these are also shown in Table 3.

Table 2. Factor loadings for the rotated solution, with Factors 1, 2 and 4 retained for interpretation. Emboldened loadings indicate significance at $p < 0.05$ level.

| Sort No. | Q sort ID | Factor 1 | Factor 2 | Factor 4 |
|---|---|---|---|---|
| 1 | xivi5jal2A | 0.2224 | 0.3078 | 0.0345 |
| 2 | K-LDOwmVQO | −0.1672 | **0.5788** | −0.3933 |
| 3 | 4jxbQe1Fhi | **0.5821** | 0.2890 | 0.1492 |
| 4 | 7VDzkrhECj | **0.8295** | 0.0309 | 0.2162 |
| 5 | zHm7cJjYNc | **0.8337** | 0.0931 | 0.0644 |
| 6 | zRM7Tnz-rT | 0.4279 | **0.4740** | 0.1121 |
| 7 | ZWVKxWxQyJ | 0.4408 | **0.6834** | −0.1537 |
| 8 | YIDj72B4Ax | 0.3189 | 0.1885 | **0.6650** |
| 9 | 83RFX6bB9I | **0.6827** | −0.1279 | −0.2306 |
| 10 | HaAmcE-jn3 | **0.5270** | 0.5136 | −0.0932 |
| 11 | KG9SzAFCk4 | 0.3905 | **0.4341** | 0.1856 |
| 12 | 0HDKHEayj7 | **0.5041** | 0.0861 | 0.2841 |
| 13 | iWn6ImXos- | **0.5194** | −0.0645 | −0.2653 |
| 14 | MLYHBmtVTA | **0.7887** | 0.1771 | −0.4153 |
| 15 | yK-W1W90IG | 0.4153 | **0.5004** | 0.0541 |
| 16 | LKXMH6lZmj | **0.6923** | 0.1016 | −0.4419 |
| 17 | GYstcF70vq | 0.2829 | **0.5987** | 0.1203 |
| 18 | ph1ooyLvuM | −0.0330 | **0.5375** | 0.1385 |
| 19 | 92woxQ7coP | −0.0215 | **0.7567** | −0.1420 |
| 20 | lu1xGyW1bV | 0.0353 | **0.8008** | 0.1099 |
| | % Explained Variance | 25 | 19 | 7 |

### *The rotated solution*

The following results describe the Factors or composite viewpoints that are made manifest through the sorting process, and their collective analysis. As Table 2 infers students can hold one, some, or all of these viewpoints at the same time (plus minor ideas not discussed here). The way they combine and balance these viewpoints is what gives each student their individual view of the VR experience.

### *Rotated factor 1 – The enthusiastic explorer*

This factor is associated with participants who found the use of VR freeing, exhilarating, and conducive to exploring much more of the landscape under study. Indeed, these are views that appear to distinguish this Factor from others. This viewpoint sees the VR experience as improving the appreciation of various aspects of landscape, being able to view the landscape from many angles and making the form of the landscape more concrete than conceptualising 2D maps in 3D does. Additionally, using the models for data collection, as opposed to just site visualisation, was perceived as useful for learning.

Participants who load to this Factor may suggest no frustration with this experience being virtual, and, thus, less realistic and detracting from the learning experience with Statement 8 being distinguishing for this Factor. Allied to this, the simplicity of the experience was a bonus, meaning the exercises could be undertaken easily and by anyone, even with relatively basic IT hardware. This rejection of traditional data recording techniques is emphasised by Statement 23 (“It is all too complicated; just give me a compass-clino, GPS, measure and field notebook”) scoring highly negatively, and being a distinguishing statement for this Factor. This viewpoint identifies a couple of benefits of using VR over real-world investigation but never confuses these benefits with

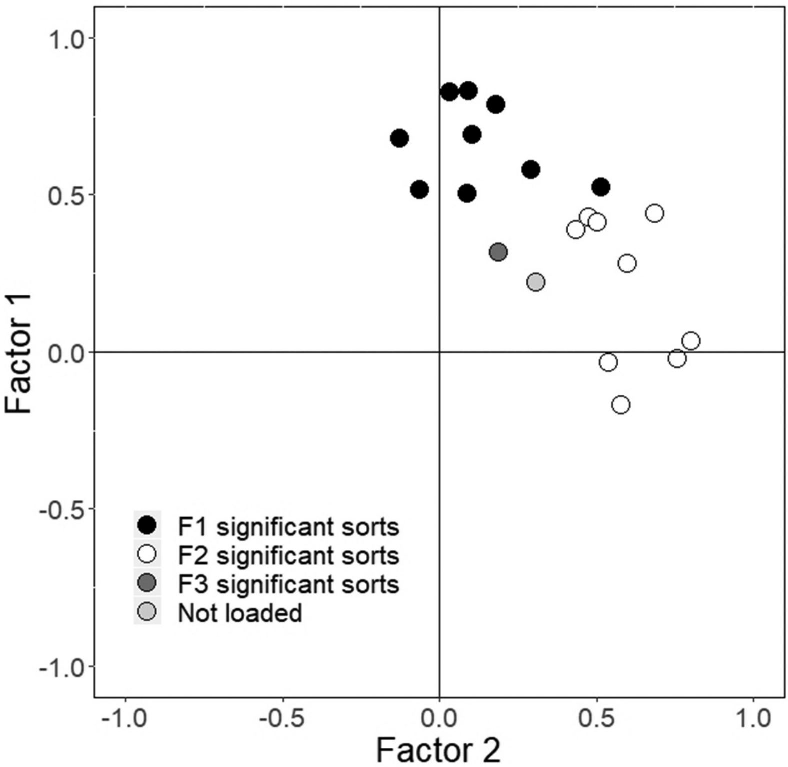


Figure 3. Loadings to newly rotated Factors 1 and 2, with fills identifying sorts that load to each factor in the solution.

those of being at the rock face for real. There is no overriding sense that the VR experience made landscape analysis, or working conditions in general, any easier, just appreciation of the 3D space better than conventional mapping products.

In terms of realism, this viewpoint does not express a strongly negative opinion of the VR model be it in terms of the representation of the environment or the representation of self. Nor is there a strong sense, in either direction, of place. There is also a relatively ambivalent position with regards to the social nature of the experience; the ability to talk through work, rely upon one's own field skills, learn from each other, or rely upon feedback from tutors.

Statements 13, 2, 21, 20, 30 and 25 are ranked higher by this viewpoint than elsewhere, suggesting that this Factor represents the views of participants who prefer working and exploring the landscape independently, and buying into the sense of realism. These points are supported by the fact that statements 27, 16, 5, 14, 22, 9, 6 and 7 are ranked negatively, and ranked much lower than on other Factors.

This analysis appears to be supported by qualitative comments left by participants who have significantly loaded to this Factor (i.e. their individual viewpoint is strongly associated with the characteristics of this Factor):

**Table 3.** Composite factor arrays for the rotated solution, with three factors kept for analysis. Scores range from −4 (most disagree) to +4 (most agree).

| | Statement | F1 | F2 | F4 |
|---|---|---|---|---|
| 1 | Seeing the landscape in three dimensions gives me a better appreciation of it than maps and charts ever could | 2 | 3 | 2 |
| 2 | Being able to visually see the form, and functions, of different landscape features will help identify them in other sites. | 3 | 1 | 1 |
| 3 | I usually struggle to visualise contour and geological maps in three dimensions, so this experience tells me so much more than a map could. | 1 | 0 | 4 |
| 4 | The experience flying around the landscape really makes me feel like I was there. | 0 | −4 | 2 |
| 5 | It did not feel like being in a natural environment at all | −1 | 2 | 0 |
| 6 | It felt sterile, as you were floating above the landscape that was not connected to anything else. | −2 | 0 | −1 |
| 7 | I found navigation tricky; I stopped wanting to explore | −3 | −3 | 0 |
| 8 | It was like pretending, and this distracted me from using the experience to learn | −4 | −1 | −3 |
| 9 | I found the blocky nature of the model close up off putting; it isn't realistic at all! | −2 | 0 | −1 |
| 10 | I found completing the exercises really easy, much better than having a bulky field notebook | −1 | 0 | −2 |
| 11 | By being able to smoothly fly around and along features, I gained a better perspective of their form and function | 2 | 4 | 3 |
| 12 | The experience was all a bit clunky; the PC is not good enough to give a good experience | −1 | 1 | −2 |
| 13 | I felt much more free to look around, and follow my own interest, than be guided to specific sites and problems. | 3 | −1 | 0 |
| 14 | If I was just using maps and photos I would have completed my task and not bothered looking at other things. | −2 | −1 | −2 |
| 15 | It was fun, I spent much more time looking around, exploring, and collecting data than I probably would have done in the field. | 4 | −2 | 1 |
| 16 | Not being able to see myself, or my classmates, made me feel disembodied | −1 | 0 | 4 |
| 17 | It was a good review or introductory experience, but it is not the same as me being there | 1 | 4 | 1 |
| 18 | It feels undemocratic; only students with good IT skills or a background in gaming would find this useful | −3 | −3 | −4 |
| 19 | I can collect my own data, and rely upon my own skills and work ethic | −1 | 2 | −3 |
| 20 | I think that, by using this d experience, I started to explore the landscape more independently, without having to be questioned or instructed to do so. | 2 | 0 | −1 |
| 21 | Being able to collect data, for later discussion with my peers and tutors, increases my understanding of the subject | 2 | 1 | 1 |
| 22 | The experience was not intuitive; it took me some time to master the tools by myself | −2 | −2 | 3 |
| 23 | It is all too complicated; just give me a compass-clino, GPS, measure and field notebook | −4 | −1 | 0 |
| 24 | I miss not being able to directly talk about what I am measuring with my classmates | 0 | −1 | 2 |
| 25 | I liked the sense of flying alone; I don't need to talk through what I am doing with anyone | 0 | −2 | −4 |
| 26 | Even though not there in real life, I could still talk meaningfully to my classmates about the exercises | 1 | 2 | 0 |
| 27 | It was still important to have a tutor on hand to ask questions to | 0 | 1 | 2 |
| 28 | Not being able to see what others are doing means that I cannot quickly copy their actions; I have to learn to do it for myself | 0 | 1 | −1 |
| 29 | Because I could fly or walk quickly over the terrain, I was more likely to investigate more of the landscape | 4 | 2 | 0 |
| 30 | Even though there were no natural sounds or other sensations, it still felt like I was there | 1 | −4 | −2 |
| 31 | I liked that we could move to sites much more directly, without having to walk for miles. | 1 | 3 | −1 |
| 32 | I much prefer these working conditions. The sun always shines in VR! | 0 | −2 | 1 |
| | **Explained Study Variance (%)** | **25** | **19** | **7** |
| | **Number of sorts significantly loading to factor** | **9** | **9** | **1** |

"It can give us some new perspective of the environment, we are not limited by a 2D view, we can actually see the details, the differences in slopes, the gullies . . ..This experience allows us to see more and discover more features about the environment we are studying"

Participant 4

"With VR you are able to explore at your own pace and spend as long as you want in different areas. . . .. it is also peaceful which means you aren't distracted and you get to think in more detail about what you are seeing whilst also conducting further research to help you understand this."

Participant 16

" . . . Is as immersive as a well-developed game."

Participant 13

### *Rotated factor 2 – The underwhelmed pragmatist*

A Factor 2 viewpoint is, perhaps, less impressed with the experience, much preferring the traditional field-based approach, as it views the experience as somewhat artificial. The highly positively rated Statement 17 ("It was a good review or introductory experience, but it is not the same as me being there") is indeed a distinguishing feature of this Factor, as is the highly negatively rated Statement 30, with Statement 4, 5, and 32 also distinguishing. There does not seem to be a view that things are overly complicated, significantly unrealistic, or even just useless, more a sense of being underwhelmed by the whole experience when compared to the views expressed by Factor One. There is less of an obvious acceptance of the virtual world, or, perhaps, more accurately, a greater rejection of the experience as "real", citing technological reasons linked to both hardware and software.

However, there is a muted sense that the freedom to move around at will helps understand the landscape in 3D better than more traditional 2D products. Thus, this viewpoint appears to welcome the simple, open way in which the landscape can be interrogated. There is a sense of the pragmatic here, with students welcoming the fact they could complete tasks speedily, on one's own using flying as a means of covering more area, although perhaps more as a means of looking around rather than collecting more data.

There is a different idea of the social dimension of the experience, when compared with Factor One. Whilst understanding that using results of the exercise could later inform discussion, all of which is useful to learning more about the landscape through constructing understanding together, this social interaction might be less focused on their peers, and more upon interaction with their tutor. There is a clear ambivalence of placing themselves within this wider experience, and their peers are more people to mimic than specifically learn things from. This sense of independent learning is relatively less positively expressed than in Factor One.

The overall view that this Factor expresses some positive benefits to learning, but feels that the lack of a realistic experience inhibits a real enjoyment and positive experience is highlighted by statements 1, 26, 5, 12, 28, 6, 9, and 10 were ranked most highly in this Factor, whilst statements 3, 13, 15, 32, and 7 were ranked most negatively, when compared to other viewpoints. There is almost a sense of participants relating to this viewpoint wanting to be left alone, to get on and do what needs to be done – and no more – as highlighted by the relative rankings given to statements 31, 19, 24 and 22.

This analysis appears to be supported by qualitative comments left by participants who have significantly loaded to this Factor:

"Field is unique, it cannot be replaced by anything . . ..The flying caused me headache, and the quality of the model is not the best"

Participant 2

> "It was nice, but seeing a profile in front of you and having a teacher explain everything is probably the best academic/educational experience I have."
>
> Participant 17

> "I have been to Blackgang Chine before, so I know what it's like to be there . . .. this certainly didn't feel like it. Also the graphics were not the best, I couldn't work out some of the features. Lastly, the houses were a bit distorted and so this threw me off a bit, I can not be fully sure that the rest of the map is not distorted?!"
>
> Participant 18

### *Rotated factor 4 – The disappointed sensation-seeker*

Whilst the holders of this viewpoint see real benefit for learning through the whole VR experience, communicating far more than traditional 2D products ever could, there is a clear sense of finding the experience isolating, with a lack of being able to discuss results with one another or a tutor. The lack of interaction expressed in the extreme ratings for Statements 3, 16, 19 and 25, in particular, are seen as distinguishing features of this viewpoint.

The viewpoint establishes benefits to learning, but it does find the process functionally trickier that other viewpoints suggest. Realism, in terms of using the model itself, is not the major issue here, nor is the experience impacted by the capabilities or IT facilities of the participant. However, there is a view that the physical experience of "being in the field" is not recreated well, and a more traditional approach to data collection and analysis is still preferable. In short, this viewpoint may see that there is little extra to be gained from this experience other than a satisfactory way to review or be introduced to a field site.

This analysis appears to be supported by qualitative comments left by one participant who significantly loaded to this Factor:

> "Working in the field is much easier and more involved. It's a great opportunity to make new relationship and share ideas with each other . . ..I agree because it's not always easy to visualize 3D objects from a 2D map. I think that with VR it's possible to have a chance to get a greater perception about you seeing . . ..Sharing your ideas with the team is always important."
>
> Participant 8

### *Differences of view and areas of consensus*

Factors 1 and 2 exhibit the greatest differences around statements that identify with the freedom to fully investigate the landscape (statements 15, 13, 19 and 23 all appear in the top ten statements where there is most disagreement) and a view to the experience's realism (statements 30, 4, 5, 17, 8, and 6 are all in the top ten statements of disagreement). A Factor 1 viewpoint appears to embrace the opportunity of the experience, and does not consider it as artificial as that expressed by Factor 2. In terms of differences between Factors 1 and 4, a Factor 4 viewpoint identifies a lack of social engagement as being problematic (statements 16, 25 and 20 appear in the top ten statements where there is most disagreement), and this possibly limits the potential for learning independently (statements 29, 13, and 15 appear in the top ten areas of disagreement), or less of a willingness to persevere with tricky (statements 22, 23, and 7) and, perhaps, unrealistic scenarios (statement 30). Between Factors 2 and 4, similar messages appear in terms of areas of disagreement. Factor 2 still differs with respect to issues of realism. However, there is a subtle difference in opinion here. Factor 2 appears to rate the “field space”, or model, as unreal (statements 4, 22, 16, 32 and 17 appear in the top ten statements where there is most disagreement, with Factor 2 rating them negatively), whereas Factor 4 viewpoints rate the “field experience” more negatively (statements 19 and 31 are in the top 10 most differently ranked statement, always negatively by Factor 4). In terms of freedom to learn, Factor 4 was always more positive, and this differed markedly from a Factor 2 viewpoint (statements 3, 12 and 15).

In terms of consensus between all three viewpoints, it appears that there is relative agreement that the VR experience adds utility to the investigation of landscape (statements 21, 1, 14, 11 are all identified as statements that are similarly positively received in all three viewpoints). However, whether this extends beyond that gained from using more traditional 2D products such as maps and photos is questionable (statement 14 is always negatively rated, as is statement 10 in two cases, and rated 0 by Factor 2). There was still an important role for social interaction with peers (statement 26) and tutors (27), although this was about the role of questioning and discussion rather than just being told what to do (Statement 28). Finally, all viewpoints strongly felt that such an experience was open to all, regardless of hardware capability to familiarity (statement 18).

Figures 4 and 5 show the relationship between self-declared capability with IT and familiarity with gaming and the predominant viewpoint that these participants load to. There is a clear relationship here; participants who declare themselves most familiar and confident with IT, and most experienced dealing with gaming environments tend to be associated with Factor One, whereas those participants who declared themselves less confident with IT and with no experience of gaming environments tend to load more often onto Factor 2.

## Discussion

The interpretation of the viewpoints above highlights a number of important implications for the development of virtual reality as a tool for carrying out fieldwork. Firstly, it appears that, no matter what the experience itself is like, there is a strong association between this experience and previous levels of engagement with IT and gaming environments. Authors such as (Biggs, 1979) and (Trigwell & Prosser, 1997) have written extensively about how prior educational experiences, approaches to learning, and attained learning outcomes are linked. These findings seem to echo points of this work such that the antecedent experiences of students (for Biggs, the “presage”) play a large part in the way they view their learning activities. It cannot be deduced from this study whether these perceptions are directly linked to a learning approach, and no previous author claims as much, but the constant interplay of antecedent experience, approach to learning, and potential outcome has been previously noted. Moreover, this model might also show a Law of Diminishing Returns, such that instructors can carry on making what they feel are the most engaging and visually accurate resources that it is possible to make, when the predominant viewpoints identified within this study show that such effort might yield little in terms of learning. In other words, the relationship between fidelity of representation and learning gains can only be pushed so far. This is because unless instructors have significantly taken into consideration the previous experiences of their students then there will always be a tendency for those students to ally themselves to one of the two most fundamental viewpoints expressed within this study. In short, those students who are experienced, able, and

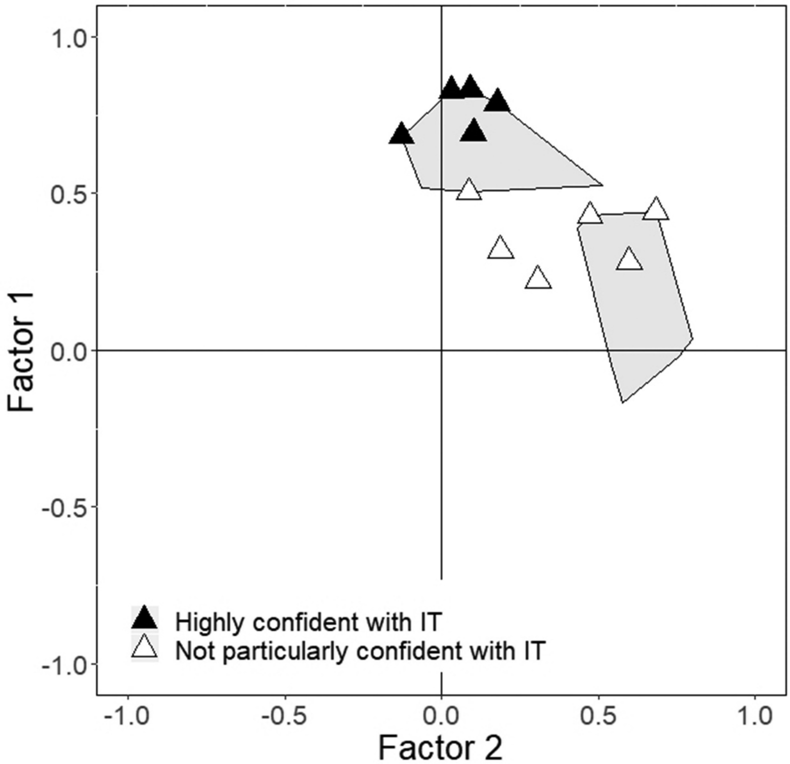


Figure 4. Factor 1–2 factor space, with boundaries representing the space represented by significant sorts for Factors 1 and 2. The fill represents self-declared data around confidence of use of IT.

potentially partial to computers and information technology, appear to be more roundly engaged with, and enjoy, the virtual reality experience, than those that are not, and so do not, and design factors that govern the VR experience itself are secondary.

This, then, leads to a number of implications for teaching students. If the aim of these VR exercises is to substitute for fieldwork, and be used to drive the assessment of outcomes, not taking into consideration these presage factors is unfair to a cohort of students. It would be unwise to assume that all students engage with technology, or have the opportunity to engage with it, in the same way. Thus, launching students into these kinds of exercises, particularly if these exercises form part of a summative assessment diet, could yield outcomes which neither serve students nor teachers well. Understanding how students view the use of IT is just a start, as the exercises also require motor skills and technological savoir-faire that some students, even those competent in a range of IT tasks, may have no experience of. Therefore, careful support and scaffolding is required to allow students to better embrace these experiences, and plenty of time should be allowed for exploration and “trial-and-error” discovery to help ease students through their early VR experiences, a view supported by Detyna and Kadiri (2020). Finally, it is important to remember that students self-declared in this study, in terms of IT and gaming experience, and it should be noted that this is not the same as an objective view of these

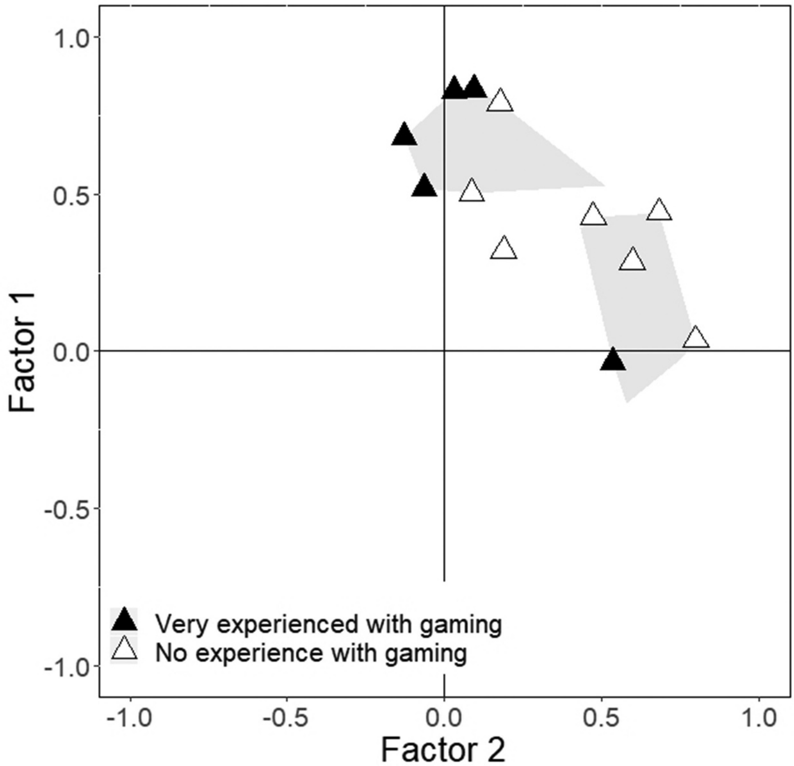


Figure 5. Factor 1–2 factor space, with boundaries representing the space represented by significant sorts for Factors 1 and 2. The fill represents self-declared data around experience of gaming.

terms. Over or under confidence with technology may mean that a typical skills audit is insufficient in understanding the presage conditions with which these students approach their task. Such a conclusion lends support to the idea of "Perceived Ease-Of-Use" as defined by (Venkatesh & Davis, 2000); students who feel they are able and experienced with IT may broadly identify such a VR experience as easier to use than those without such characteristics, and thus embrace the experience in a much more positive manner.

Secondly, the inclusion of Factor 4 in this analysis shows that there is a significant view that being in the field is, perhaps, a more visceral process then we may give it credit for. This means that instructors and designers can spend as much time as they like perfecting the realism in the 3D models; taking better data, building finer, more detailed meshes, getting colour balancing exact, worrying about occlusions and the like. These data suggest that these may be of secondary importance to this viewpoint. Factor 4 serves to remind those building VR experiences that fidelity of the environment (the model, in this context) is not particularly important because the experience itself does not mimic what this viewpoint might consider most important in the field work experience; the exertion and perseverance in reaching a field site, the feel of the Earth under one's boots, the casual chatter amongst colleagues and classmates, and the overall embracing of being out in the open air.

How, then, might teachers bring round those who identify strongly with a Factor 4 viewpoint? From a technological angle, these data suggest a rethink of focus, away from model fidelity, and more towards the social experiences of the field. This might be about a more “Second Life” experience (Warburton, 2009), where avatars can see each other in VR. Or it might be that teachers just acknowledge that not all are going to engage with this experience in the same way, which, in itself is also true of “real world” fieldwork. It is important to remember that Factor 4 does not point to an antagonistic view of the experience, just a preference for the real thing, such that it is a timely reminder that not everyone is an enthusiast, and that the learning preferences of students are many and varied and need to be managed sympathetically. However, it is worth noting that previous studies have suggested that this level of interaction is important for learning in these environments (Philips et al., 2015)

Thirdly, there appears to be an interesting difference of opinion over what does and does not constitute “reality”. Students who more keenly associate with Factor One do not see the artificial nature of the virtual reality experience as being problematic. However, those who more significantly agree with Factor Two apparently refute virtual reality as a particularly good approximation of the real world. It is unclear from this data whether this represents a set of IT literate students who are so engaged with the world of computer games that their view of reality is perhaps different, or whether the same set of experts are so used to an unrealistic version of reality that they are accepting of the problems and pitfalls that beset the construction of such artificial 3D worlds. Similarly, it is unclear whether students less familiar with the gaming world set higher expectations of the experience, and this antagonism is just a register of their disappointment rather than dissatisfaction.

Finally, it is important to consider how such an intervention fits into the panoply of exercises that students undertake whilst studying subjects like geohazards. It would appear that Factor One is one viewpoint that is more accepting of using virtual worlds to explore real-world field sites than others, but it is important to note that such a viewpoint represents only a quarter of the whole study variance, and is associated with less than half of the participants. The rest of the study variance, and its significantly loaded participants, are, perhaps, less enamoured by the approach, yet at no stage do they reject it out of hand. Thus, this study neither confirms nor refutes that such an intervention is a panacea for issues of student satisfaction, rather that such interventions should be used cautiously and reflectively in order to allow students to achieve what they can whilst keeping potential costs and health and safety concerns down. Thus, it might be that, instead of seeing such advances as substituting for fieldwork, they are for training, familiarising, and revising. Such a conclusion may agree with past work on students’ views of fieldwork where the benefits they feel they gain from being in the real world, measuring data in the raw, go far beyond the intellectual challenge of the interpretation of natural data themselves.

## Conclusion

Whilst acknowledging the centrality of fieldwork to the teaching and learning of Earth and Environmental Sciences, it is important to acknowledge that such activities are costly, logistically challenging, the source of concern in terms of personal safety, and a real challenge for students with limited mobility. Being thrust into focussed activity, often in confined social spaces, is also a challenge for some. Thus, finding meaningful alternatives to traditional fieldwork clearly has a range of benefits. However, until recently, virtual fieldwork has often consisted of photo tours, pre-constructed data sets, and no real sense of the field site under investigation.

The 3DTeLC project has used 3D data and models, combined with readily accessible games engine software, to produce an experience that students can move around, interact with, make choices about what data is required and where it can be collected, ready for analysis by more conventional means. The high degree of absolute and relative accuracy afforded by well collected UAV data means that these measurements can be georeferenced and used for GIS analysis, much as they would in more traditional mapping contexts.

This study has evaluated the student experience in terms of using ones of these VR models. It has found that well over half the study variance is encapsulated by three viewpoints. In terms of survey participants who significantly associated with these viewpoints, the greatest number shared a view that was positive about the experience and the technology, and saw real benefits in the approach. The next most significant viewpoint was one that saw the experience as less than real, and in no way useful in comparison to real-world fieldwork. Finally, there was a view that the model itself was not the issue, it was the lack of other experiences such as the physical and social nature of fieldwork in the real world. It was found that students who tended to self-identify as experienced and able with IT and the gaming environment, tended to more readily associated with the first, positive, factor.

It is suggested that to best realise the benefits of such an intervention, these narratives need to be reflected upon. Firstly, by raising the confidence and self-efficacy of students less experienced with the IT and motor capabilities by scaffolding, training, and allowing students to experiment with these experiences. Secondly, to worry less about the realism of models and the variety of skills needed by an ever more complicated user experience in favour of building experiences that, at least, mimic some of the social attributes of real-world fieldwork. And, finally, recognise that whilst there was no outright rejection of the use of VR, the data suggest many ways in which students prefer "the real thing", thus keeping fieldwork at the heart of teaching activities but using VR to supplement and improve student learning.

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