



Review

The Effect of School Design on Users' Responses: A Systematic Review (2008–2017)

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Received: 27 January 2020; Accepted: 16 April 2020; Published: 23 April 2020



Abstract: This systematic review focused on the effect of the educational environment design on students' and teachers' performance, satisfaction, and wellbeing. Starting from a bulk of 1307 articles, a set of $N = 68$ empirical papers was selected and organized on the basis of four different content clusters, i.e., architectural building design and aesthetic features, indoor environmental features, classroom design, and school green spaces/outdoor spaces. From the analysis of research findings, the key role of pleasant, warm, and flexible learning environments emerged, for promoting both wellbeing and performance of users. More specifically, the presence of charming colors and pictures, ergonomic furniture, and adequate acoustic, thermal comfort, ventilation, and natural lighting have emerged as important features that school designers should care for. Furthermore, an integration of both indoor and outdoor learning situations showed to be effective for improving students' learning and wellbeing.

Keywords: school architectural features; psychological responses; learning space; students' performance; users' wellbeing

1. Introduction

School experiences may have important effects not only on students' performance, but also on their future lives. In fact, good emotional health during school age is associated with educational success, development of a healthy lifestyle, and reduced risk of adverse socioeconomic outcomes, psychiatric disorders, self-harm, and suicide in later life [1].

Over the last decade, evidence has been accumulating on the relationship between environments and users' health within a "user-centered" perspective [2]. This approach aims at planning and designing spaces that align with needs, preferences, and behavioral responses of current and potential users, as well as with the instrumental goal for which those spaces have been created. For this purpose, the interaction between the setting features/functions and the users' characteristics and activities should be taken accurately into account.

Consistent with the user-centered design approach, the construct of "design humanization" has been developed, particularly for healthcare environments [3,4], referring to those spatial-physical features that influence users' responses. Such a construct can be generalized also to other kinds of places, such as community residences for the elderly population [5] and school environments, since it refers to a set of design attributes that should be provided to satisfy fundamental users' needs [6–8]. In sum, school building design is supposed to play a central role in the creation of environments that improve educational attainment. Promoting a higher level of design humanization in a school

environment means to take into account its spatial-physical configuration, in order to increase the outcome in terms of both learning and wellbeing, especially when considering the high proportion of time that both staff and students spend at school each week.

According to the US National Research Council [9], the design attributes highlighted within the humanization framework recall those “school facility factors” (including quality of maintenance, lighting, colors, noise, temperature, and air quality [10]) that affect students’ health, safety, sense of self, and psychological state. Similarly, in the general framework proposed by Gifford [2], humanization design features can be included in those “physical features of the learning environment” that are variables (besides personal characteristics of the student and social/organizational climate) influencing students’ attitudes toward learning (such as desire to learn and satisfaction toward the school experience) and related behaviors (such as performance and participation/involvement). In this regard, a lot of empirical evidence has been produced concerning these effects on an array of individual and social outcomes, of specific school design attributes, such as state [11] and dimension of the school facility [12,13], noise [14–16], temperature and indoor air quality [17–20], classroom lighting conditions [14,21], spatial layout [22–27], interpersonal distance [28,29], personalization of spaces [30], furniture quality [31,32], and the presence of natural elements in outdoor spaces [33–35].

Whilst numerous researchers have systematically investigated literature about the effect of specific aspects of a school’s environment on performance and wellbeing [1,36], uncovering a variety of relations in the process, there has been no attempt to synthesize and summarize this accumulation of evidence in a coherent manner. Indeed, from a preliminary analysis of existing literature on the topic, it seems that no review has drawn together this evidence specifically examining the impact of different features of school buildings—such as architectural design, aesthetic quality, spatial and physical characteristics, internal layout and furniture, and external spaces—on students’ and staffs’ psychological responses, which include patterns such as learning outcomes, needs, preferences, expectancies, emotions, choices, and behaviors.

A systematic review of the latest available literature about the effects of different aspects of school-built environment on learning and wellbeing could be useful both for the development of research in this field, through the identification of those features of the built environment which weigh more on users’ performance, comfort, wellbeing, and satisfaction, and for designing and redesigning/retrofitting school buildings to enhance the valence of users’ educational experience. Hence, the proposal of this review is to identify the existing research literature published in the last ten years on the relationship between school environment and school users, in order to provide a general picture about recent findings on this topic and open future avenues of research.

The structure of the review is organized around four main clusters of school features, which are related to place satisfaction [2,37] and refer to different levels of environmental scale. This is in line with the conception of the environment as a multi-place system [38], which relies on Bronfenbrenner’s systemic view [39], applied also to healthcare environments [3,7]. More specifically, the first two clusters of school features concern a molar environmental scale (tapping both outdoor and indoor environment aspects) and include respectively *school building/architectural design/aesthetic features*, such as school building size, building aesthetics, refurbishment, and *indoor environmental features*, such as lighting, temperature, and acoustic. The third cluster is about *classroom design/furniture*, that is at a specific (indoor) level of environmental scale. Finally, the fourth cluster focuses on *school green spaces/outdoor spaces* with regards a specific (outdoor) level of environmental scale. Following this distinction, the review aims to give answers to four main questions:

- 1) What is the evidence for the association between the *school building/architectural design/aesthetic features* and users’ psychological responses, and which environmental factors have the greatest impact?
- 2) What is the evidence for the association between the *indoor environmental features* of the school place and users’ psychological responses, and which environmental factors have the greatest impact?

- 3) What is the evidence for the association between *classroom design/furniture* and users' psychological responses, and which environmental factors have the greatest impact?
- 4) What is the evidence for the association between *school green spaces/outdoor spaces* and users' psychological responses, and which environmental factors have the greatest impact?

2. Materials and Methods

The review focused on the effect of the educational environment design on students' and teachers' satisfaction, performance, and wellbeing. The specific inclusion criteria used for the selection procedure are addressed in the following paragraphs.

2.1. Search Methods for the Selection of Studies

The literature search was carried out from September to December 2017, using EBSCOhost Integrated Search (including Academic Search Complete; Art & Architecture Complete; Humanities Source; Applied Science & Technology Source; Environment Complete; SocINDEX with Full Text; Education Source; MEDLINE Complete; CINAHL Complete; Psychology and Behavioral Sciences Collection) across different fields of interest, such as arts and architecture, computer science and engineering, Earth and environment, education, health sciences, life sciences, psychology, and sociology.

Previously specified search criteria were defined before the search phase: The review was restricted to English language full-text articles, published in academic and scholarly peer-reviewed journals. In line with Pullin and Stewart's Guidelines for Systematic Review [40] we adopted a holistic approach, by including a large number of variables limiting the number of studies. To this aim, we limited the search to the previous decade (i.e., publication date ranging from 2008 to 2017).

The selection process was oriented by the distinction of the four different clusters of school features previously reported, thus four distinct searches were carried out, one for each cluster.

Using Boolean operators, specific keywords combinations were identified for each cluster. All clusters had a mean string [*learning OR wellbeing OR well-being OR well being OR satisfaction OR drop-out school OR socialization OR socialisation OR place attachment OR place identity*] including all the (assumed) outcome variables, combined with AND and—for each cluster secondary strings, representing all the (possible) exposure measures, as follows:

- 1) [school design OR school building OR architectural design] for the first cluster;
- 2) [lighting OR noise OR acoustic OR temperature OR ventilation] AND [school OR classroom] for the second cluster;
- 3) [classrooms design OR layout OR furniture] AND [school] for the third cluster;
- 4) [green spaces OR green areas OR outdoor] AND [school] for the fourth cluster.

Keywords had to be included in the articles' abstracts.

2.2. Criteria for Inclusion

All articles were included if at least one exposure measure and one outcome variable were present. Studies were excluded if (1) they addressed only exposure measures; (2) they included only outcome variables; (3) the educational setting did not represent the research focus (this review refers to schools from kindergarten to secondary school, since we did not include terms such as "university" or "college" or "higher education" in our search. Following this rule, we removed nine papers from our selection because they concern higher education places); (4) they regarded an irrelevant topic; (5) they were more pertinent to another cluster (and in such a case they were moved to that cluster).

During the revision process, two independent judges (i.e., the first and the second author of this article) assigned a value of 0 (i.e., exclusion) or 1 (i.e., inclusion) to each article and, subsequently, they assessed the inter-reliability for each cluster. Furthermore, all the articles were marked on the basis of the motives for their exclusion. Percentages for each reason of papers' exclusion are as follows:

1. Only exposure variables were addressed: 5.3% of papers;
2. Only outcome variables were included: 15% of papers;
3. The educational setting did not represent the research context: 5.6% of papers;
4. The research focus was an irrelevant topic: 73.6% of papers;
5. Another cluster was more pertinent for their inclusion: 0.5% of papers.

2.3. Inter-Rater Reliability

Articles emerged from each of the four searches were independently screened for relevance—first by title and abstract and then by full-text—by the two judges, then their inter-rater reliability was assessed through the Cohen’s Kappa coefficient, which on average of the four clusters resulted equal to 0.56 (lying in the upper portion of the “moderate” agreement interval, see [41]). Finally, inconsistencies about the inclusion/exclusion of articles in the review was solved through discussion to reach a perfect agreement between the two raters.

3. Results

A total of 1307 articles were identified, 420 of which were immediately removed due to duplicate publications. A total of 887 studies were then screened through an analysis of the abstracts and 814 were considered unsuitable for inclusion (see exclusion criteria 1–4). Sixty-eight studies were reviewed through an analysis of the full-text and were finally selected and included in the review (64 relevant for the topic of each cluster and four studies moving across clusters). A summary of the literature review process is shown in Figure 1.

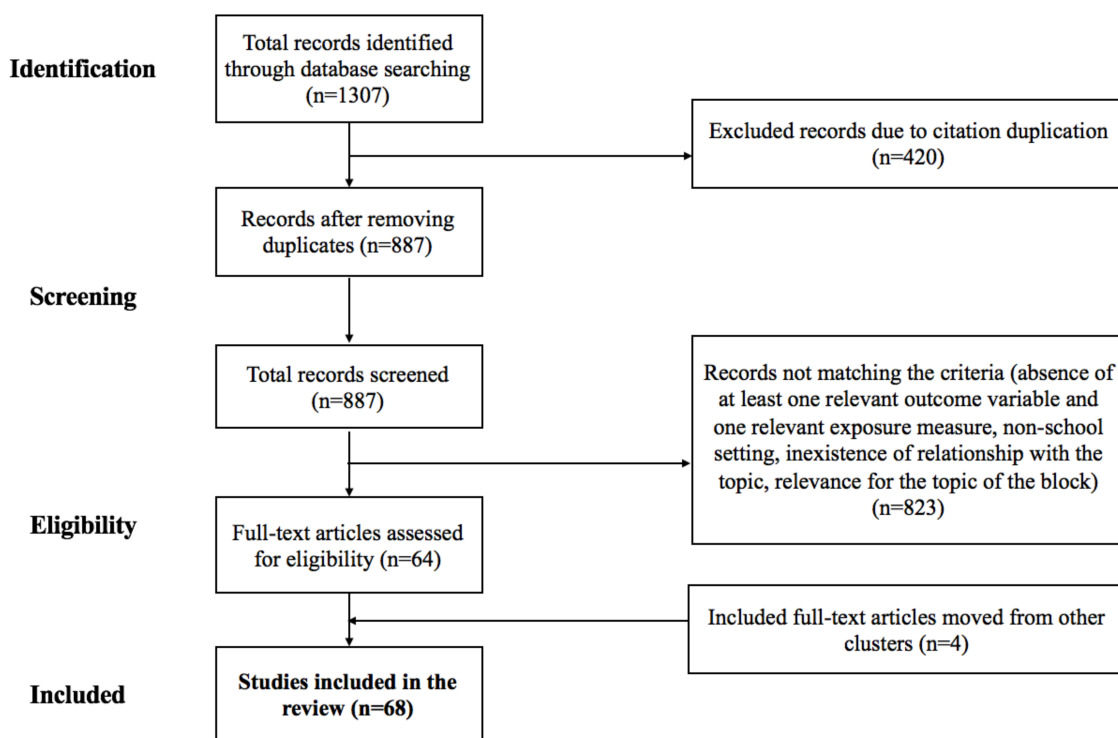


Figure 1. Summary of the literature review process.

Table 1 shows the variables considered by the studies that fulfilled the inclusion criteria for this review. *Indoor environmental features* of school buildings are the most considered cluster of exposure measures variables (Cluster 2), followed by the *outdoor and green areas* cluster (Cluster 4).

Table 1. Summary of the reviewed studies.

	Quantitative Study	Qualitative Study	Mixed Design	Total
School building/architectural design/aesthetic features	5	5	0	10
Indoor environmental features	19	1	2	22
Classroom design and furniture	2	8	2	12
Outdoor and green areas	4	18	2	24
Total	30	32	6	68

Tables 2–5 report information about the reviewed studies for each of the clusters, specifying authors, research design, participants (number of schools involved, sample size, age, and country), exposure measures [1], outcome measures, and relevant results are reported. Following the graphical schematization used by a systematic review about the relationship between school furniture and students' performance, the effect of the exposure measure was classified as (+) when the effect resulted in an improvement in the outcome variable, (–) when the effect was negative, (0) when there were no change, and (+/–) when the results were not clear [36] (p. 96).

Considering all the selected studies, the most studied outcome variable was “learning,” found in 62 studies (also in terms of “performance,” “education,” “teaching,” “learning environment” on the whole), followed by studies that presented “wellbeing,” tested 14 times (also in terms of “comfort,” “health,” and the other outcome variables examined in other studies, “satisfaction” in five studies, “socialization” in seven studies, “place identity” in two studies) (in particular, “learning” has been operationalized in terms of individual level score in task performance (e.g., [42,43], a specific measurement scale (e.g., [44,45]), teachers' and students' observation and/or interviews (e.g., [46,47]), acoustic perception (e.g., [48,49]), and visual and audio data collected (e.g., [50]). As concerns “wellbeing,” it has been operationalized through specific measurement scales (e.g., assessing parental involvement, contacts with friends, and general well-being: [51]; or physical comfort: [52,53], students' and teachers' interviews (see [54]), speech measurement through objective parameters of noise and sound (see [55]), and observation of students' posture [56]).

Two outcome variables, “drop-out” and “place attachment,” did not emerge among search results.

3.1. Effects of School Building, Architectural Design, and Aesthetic Features on Students' and Teachers' Psychological Responses

Starting from 1307 total articles, this cluster identified 819 initial papers, 537 of which were reviewed due to duplicate publications. A total number of 10 articles was finally included (Table 2).

Table 2. Studies on the effects of school building, architectural design, and aesthetic features.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Age (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
1.	Cencič (2017)	Quantitative study	n = n.s. pp = 150 school leaders in primary education yr = 31—more than 61 c = Slovenia	Age of the school building (new building: Less than five years; old building: More than five years; or renovated school)	Evaluation of learning environment (factors: Imagination, creativity, feelings, language, music, logic and mathematics, space, movement, ecology, aesthetics, cooperation among students, respect, ethics and attitude towards the broader community)	(0) New and renovated schools were given less preferences over old buildings with respect to cooperation among pupils, language, and ethics, although with no statistically significant differences. (+) New schools only scored slightly higher than old and renovated buildings did in the factors of ecology, attitudes towards broader community, music, aesthetics, feelings, imagination, and space. (−) Their estimates of the assessed factors differ depending on the type of school building (new, old, renovated) only on the factors of movement, creativity, and logic and mathematics in favor of old schools.
2.	Ghaffarzadeh (2016)	Qualitative study	n = 10 pp = 260 students, female yr = third year of secondary school c = Iran	Rating of physical environment (excellent, medium, or inappropriate) and type of schools (timeworn, new, or refreshed)	Learners' and teachers' educational behaviors; education discrimination	(+) The private schools with excellent physical environments were found to have a higher cooperative learning method than public schools with inadequate physical environments: Understanding; less cheating; considerable attention; reasonable teacher behaviors regarding learners' mistakes; student involvement in the teaching/learning process; cooperative teaching; meaningful learning; less stress; communicative language teaching (CLT).
3.	Lumpkin (2016)	Quantitative study	n = 15 primary school, n = 10 junior high school, n = 12 senior high school pp = n.s. yr = fourth, eighth, ninth, and tenth grade students c = Florida (USA)	State of school facility (old or new buildings)	Academic achievement of students (measured by the mathematics and reading subtests)	(+) Results indicated that the aggregate passing percentages on the mathematics and reading subtests increased when students attended a new 2000 UBC (Uniform Building Code) school facility.

Table 2. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Age (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
4.	Slunjski (2015)	Qualitative study	n = 7 institutions Pp = n.s. yr = preschool c = Croatia	Spatial organization and structure of the school (e.g., size of the institution)	Quality of educational processes	(+) Inadequate size of early childhood education institutions—too large facilities aggravate the quality of the child’s education, since they inhibit the possibility for the child to develop his/her identity.
5.	Stringer, Dunne, and Boussabaine (2012)	Quantitative study	n = 15 secondary schools pp = heads of the schools and their facility management representatives yr = n.s. c = UK	Rebuilding, refurbishment, renewal, or new opening school building	Users’ perceived design quality of school (e.g., sense of place, orientation, clarity, efficiency, building performance)	(+) From the analysis and discussion of these results, it is suggested that the issues relating to site, which are the clarity of the building envelope and creation of a public presence, appear to have been resolved in the opinion of the survey respondents. Another area that appears to have improved greatly is circulation, that is how “easy [it is] to find your way around the school.” (−) However, the other areas of concern remain unsatisfactory. Material specification performed very poorly as did the quality of building maintenance.
6.	Duca (2012)	Quantitative study	n = 1 pp = 87 pupils and 8 teachers yr = third, fourth, and fifth grade of primary school c = Italy (Naples)	Characteristics of building and urban surroundings	“School usability,” investigated in terms of effectiveness, efficiency, and satisfaction of school building (as possible indicators of learning outcomes)	(−) Learning activities, especially under the user’s satisfaction point of view, are only relatively affected by buildings fully compliant with Italian regulations. On the contrary, many of the relevant characteristics are out of the regulatory field; inadequacies related mainly to a macro scale level (urban context) or to a micro scale level (technical devices, finishes, furniture).
7.	Leiringer and Cardellino (2011)	Multiple case study	n = 4 pp = n.s. (head teachers, teachers, and other related staff) yr = n.s. c = Sweden and Denmark	Building design (design of school environments, e.g., open and transparent designs)	Teaching and learning	(−) Open and transparent designs (e.g., interior windows or the lack of interior walls) are encouraged and flexible learning environments are consistently promoted as facilitating changes in teaching and learning approaches. However, there was agreement amongst teachers and parents that the extreme transparency of the space had a negative effect on certain pupils’ behavior (e.g., more distraction, worse acoustic, less privacy for the pupils and teachers)

Table 2. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Age (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
8.	Cuyvers, De Weerd, Dupont, Mols, and Nuytten (2011)	Quantitative study	n = 14 secondary schools pp = 2032 students yr = 14–15 c = Belgian region of Flanders	Impact of school infrastructure	Wellbeing of students	(+) Scores on wellbeing were significantly lower among students attending schools with poor quality infrastructure and schools with low scores on both variables (“to the extent possible, possible the classrooms open onto a (green) outside area” and “the school building provides well-integrated ICT and easy access to various sources for research”). Female students were more sensitive to school infrastructure than their male colleagues and ninth grade students were more sensitive than 10 th grade students.
9.	Wolsey and Uline (2010)	Qualitative study	n = 1 pp = 5 students yr = n.s., middle school c = USA	Physical built environment and school climate	Student achievement, and identity development	(+) When the school is constructed and used in flexible and responsive ways, students begin to think of themselves as part of the place. The place, in turn, becomes part of their identities. Their emotional responses revealed that students attached meaning to the school facilities, and they felt they needed both personal and social spaces. In addition, they connected the aesthetic features of the school environment to learning and instruction.
10.	Woolner et al. (2010)	Qualitative study	n = 1 secondary school pp = 38 teachers, 28 support staff, and 107 students yr = 7–11 (students) c = UK	Current experiences of the existing school environment (represented in pictures and maps)	Aspirations for the future, when the school would be rebuilt (to improve learning environment)	(+) There were notable differences between groups of users in their preferences for particular parts of the building, and these reflect time not only spent in different places, but also the position of the users within the school community (e.g., the students much more frequently attached stickers of both colors to places outside the school building, showing that many people consider that spaces around the building are as much part of the school as those within its walls. When staff occasionally marked outside areas, it was with red stickers to indicate places where problem behavior, such as smoking or climbing fences, takes place).

Note: n.s. = content “non specified” in the publication.

As for the sample, five studies recruited students as research participants (one from preschool, two from a junior high school, and two from a senior high school), three sampled staff (two targeted school leaders and one head teachers, teachers, and other related staff), and another two studies sampled both students and teachers.

Concerning the study design, the ten papers of this cluster present different methodologies (see Table 1). In five studies, effects of school building and architectural features were investigated using quantitative methods (surveys), whereas the remaining five studies used qualitative methods (field and case studies, observational designs, interviews). One study [57] used a causal comparative research, with a pre-post-test design comparing homogenous groups (elementary, middle, and high school students) tested before and after exposure to the intervention of interest (e.g., school building renovation).

As regards the measures, the initial search found either self-report or objective measures of effects of school building design on school users, and only one study using objective measures was identified [57], specifically students' scores at mathematics and reading subtests. Other studies used either one or more of the following types of self-report measures: Teachers' and/or students' evaluation of learning environment (three), educational behaviors (two), design quality and school usability (two), wellbeing (one), and aspirations for the future (one). The most studied outcome variable was learning evaluation (i.e., students' achievement and performance), whereas student drop-out rate was not examined in result studies.

As for the countries, the studies were mostly (70%) conducted in Europe, specifically two in the UK (20%) and the others in other different European countries. The remaining three (30%) studies were conducted in North America (two) and Asia (one).

Considering the outcome variables, the results reveal that 61.5% of the reviewed studies of Cluster 1 presented positive (+) results, 30.8% presented negative (−) results, and 7.7% presented no change (0). For example, the study of Cencič (2017) showed that the age of the school building (new, old, or renovated) has a different effect on school leader evaluation of learning environment, with new schools scoring higher than old or refurbished schools in some factors (e.g., ecology, feelings, aesthetics), and old schools scoring higher than new or refurbished schools in other factors (e.g., logic, mathematics, creativity).

Overall, this analysis highlights some strengths of this line of research. First, the literature on the effects of school building and architectural design integrates studies carried out with different methods and approaches (i.e., qualitative and quantitative) and involving different users (ranging from students at different grades to teachers and staff members). Moreover, these prior studies investigated the role of rebuilding and architectural features on several aspects of the life at school such as teaching experience, learning outcomes, satisfaction.

However, these results also underline some gaps that future studies should address. More specifically, the research showed some inconsistent or not conclusive evidence about the positive effects of renewing and rebuilding schools. Thus, to better explore the phenomenon, further investigations could take into consideration crucial moderators (e.g., place identity, gender). Importantly, most of these studies were conducted on a small number of participants, using different measures and focusing on different design and architectural aspects: If on one side the integration of different tools and perspective enriches the analysis, on the other side the comparison of results is not always possible. Therefore, additional studies should be carried out to fill this gap, taking into account the holistic nature of environmental aesthetics that requires—much more than other aspects—a bridge between complementary perspectives [58].

3.2. Effects of Indoor Environmental Features of School Environments on Students' and Teachers' Psychological Responses

Starting from 1307 total papers, this cluster identified 181 initial articles, 126 of which were reviewed due to duplicate publications. A total number of 22 articles was finally included (Table 3).

Table 3. Studies on the effects of indoor environmental features.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
1.	Mendell, Eliseeva, Davies, and Lobscheid (2016)	Quantitative study	n = 28, 150 classrooms pp = 5046 (English) +5455 (maths) yr = elementary schools c = three California school districts (USA)	Daily classroom ventilation rates (VRs) from real-time indoor carbon dioxide measured by web-connected sensors	Learning (individual-level scores on standard tests in math and English)	(+) Findings suggest potential small positive associations between classroom VRs and improved learning in English and Math among young students, but associations were of variable magnitude and with few CIs excluding the null. VRs were in most cases more strongly associated with higher test scores in the district where the VRs were very low.
2.	Petersen, Jensen, Pedersen, and Rasmussen (2016)	Quantitative study	n = 2 (two classrooms at each school) pp = 82 yr = 10–12 c = Denmark	Increased classroom ventilation rate (exposition to either recirculated air or fresh air)	Performance of children in four different tests (addition, number comparison, grammatical reasoning, and reading and comprehension)	(+) Increased ventilation rates in classrooms have a positive effect on short-term concentration and logical thinking of children performing schoolwork. Individual pupils' performance was significantly improved in four of four performance tests when the outdoor air supply rate was increased, and CO ₂ concentration was decreased. (−) Increased outdoor air supply rate did not have any significant effect on the number of errors in any of the performance tests. (+) Results suggested that the study classroom air was perceived more still, and pupils were experiencing less pain in the eyes in the recirculation condition compared to the fresh air condition.
3.	Lee, Kwon, and Lim (2016)	Field experiments	n = 4 classes pp = students yr = n.s. c = Korea	Use of an intelligent lighting control system based on context-awareness (that recognizes the locations and behaviors of the teacher and students automatically by means of sensors; grasps the current class context; and creates appropriate lighting environments accordingly)	Learning efficiency	(+) The lighting condition was comfortable and effective for learning efficiency as it was in the comfortable range of Kruihof's curve. This indicates that when applied to a classroom environment, the suggested system contributes a lot to learning efficiency improvement.

Table 3. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
4.	Akhtar, Anjum, and Iftikhar (2013)	Quantitative study	n = 4 pp = 100 students and 20 teachers yr = 10–13 (students) c = Pakistan	Noise pollution around educational area (noise level indoors-classrooms and outdoors-playgrounds)	Students' and teachers' performance and comfort (e.g., learning ability, social interaction, conflicts, headache, tiredness, attention)	(–) All four schools have noise level more than World Health Organization recommended allowable noise level. All Dependent Variables are adversely affected by high classroom noise. High background noise has a major negative impact on students' performance (most of the schools are located close to main roads).
5.	Slegers et al. (2013)	Quantitative study	n = 2; 1; 6 pp = 98; 44; 55 yr = Elementary c = Netherlands	Lighting conditions (with vertical illuminances between 350 lux and 1000 lux and correlated color temperatures between 3000 and 12,000 K)	Concentration of elementary school children	(+) The results indicate a positive influence of the lighting system on pupils' concentration. The findings underline the importance of lighting for learning
6.	Chan, Li, Ma, Yiu, and McPherson (2015)	Quantitative study	n = 37, 146 classrooms pp = n.s. yr = kindergartens, primary schools, secondary schools, and special schools c = Hong Kong	Noise levels and teacher speech-to-noise ratio	Learning and teachers' vocal health	(–) All except one classroom were exposed to excess background noise over the recommended level of 50 dBA for occupied classrooms. Teachers increased their vocal effort to overcome the high noise levels in classrooms so that their students could hear them. It could have adverse implications for student learning and teachers' vocal health.
7.	Mealings, Demuth, Buchholz, and Dillon (2015)	Quantitative study	n = 1 pp = 22 yr = 5–6 c = Australia	Two listening conditions of intrusive classroom noise. In one condition classes were engaged in quiet activities (e.g., whole-class teaching), and in the other condition classes were engaged in noisy activities (e.g., group work with movement).	Children's speech perception, listening abilities	(–) Children's performance accuracy, number of responses, and speed were lower in the noisy condition compared with the quiet condition. In addition, children's speech perception scores decreased the farther away they were seated from the loudspeaker.

Table 3. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
8.	Brännström et al. (2017)	Quantitative study	n = 4 pp = 149 yr = 9–13 c = Sweden	Acoustic environment of the schools	Children's perception of the acoustic environment of their school	(-) Crowded spaces are most challenging; the children themselves generate most of the noise inside the classroom, but it is also common to hear road traffic noise and teachers in adjoining classrooms. The extent of annoyance that noise causes depends on the task but seems most detrimental in tasks wherein the demands of verbal processing are higher. Finally, children with special support seem to report that they are more susceptible to noise than the typical child.
9.	Punnoose, Arya, and Nandurkar (2017)	Quantitative study	n = n.s., local regular English medium schools and multidisciplinary centers pp = 30 children who have been diagnosed with learning disabilities (LD) and control group has 45 typical children yr = 9–12 c = Mumbai	Presence of quiet vs. noise (four-talker babble)	Speech perception (word recognition scores) in children with LD	(-) Children with LD show increased speech recognition deficits in the presence of noise. Moderate amount of background noise can interfere with speech perception and can impair educational outcomes in children, with greater effect on younger children.
10.	McKellin, Shahin, Hodgson, Jamieson, and Pichora-Fuller (2011)	Quantitative study	n = 1 pp = 24 yr = third, fifth, seventh grades c = Canada	Noise in regular classroom activities	Structure and substance of learning in English language (students' grammatical and discourse structures, organization of conversation, and development of conceptually complex interaction)	(-) Noise levels impeded the intended development of complex conversational interactions and collaborative learning.

Table 3. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
11.	Santos, Seligman, Souza, and Rossi (2013)	Quantitative study	n = 4 pp = 87 children yr = 8–10 c = Brazil	Sound pressure levels in classrooms and changes on acoustic admittance	Auditory skills in learning process	(+) High sound pressure levels in classrooms do not interfere in children's auditory skills, in the learning process tested using the Staggered Spondaic Word Test, an instrument used to detect auditory processing problems in children with learning demoted. (+) G1 (group not exposed to levels higher than 80 dB) has showed better results in phonemic decoding; (-) G1 has shown worse results in codification and organization sub profiles.
12.	Connolly, Dockrell, Shield, Conetta, and Cox (2013)	Quantitative study	n = 6 pp = 2588 English secondary school pupils yr = 11–16 c = UK	Acoustical features of schools	Pupils' impressions of their school's acoustic environment (to ease of hearing in school spaces, sensitivity to noise, the consequences of noise in the classroom, and annoyance to intermittent noise)	(-) Pupils who reported additional learning needs reported being significantly more affected by poor school acoustics than pupils reporting no additional learning needs. Older pupils were significantly more sensitive to noise annoyance and to the consequences of poor acoustical conditions on their learning and behavior than younger pupils. (+) Pupils attending suburban schools featuring cellular classrooms that were not exposed to a nearby noise sources were more positive about their school acoustics than pupils at schools with open plan classroom designs or attending schools that were exposed to external noise sources.
13.	Dockrell and Shield (2012)	Quantitative study	n = 8 pp = 393 (survey—baseline and follow-up installation); 186 (experimental study); 14 teachers of classrooms (with sound-field systems) yr = 8–11 c = UK	Acoustical features of classrooms (installation and use of sound field systems)	Students' and teachers' perceptions of classroom environments and objective data evaluating change in performance on cognitive and academic assessments with amplification over a six-month period.	(+) Both teacher ratings and student performance on standardized tests indicated that sound-field systems improved performance on children's understanding of spoken language, especially in classes with poorer acoustics.

Table 3. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
14.	Nilforoushan, Hanna, Naeni, and Mozzafar (2013)	Quantitative study	n = ns. pp = n.s. students, teachers, head teachers, and architects yr = primary school c = Glasgow (UK)	Illumination in classroom (e.g., impact of daylight)	Student performance and health	Daylight has an impact on performance and health: (+) Light levels did affect space utilization in classrooms and pupils seemed happier and more active in sunny classrooms than in shaded ones. (+) In general, the availability of daylight in classrooms was reliably associated with an increase in student performance and learning rate of somewhere within the bounds of 7% to 37%.
15.	Mott, Thomas, and Burnette (2017)	Case study	n = 1 pp = a teacher and her classroom yr = third grade c = USA	Use of a dynamic lighting system in classroom (color, temperature, and luminosity created four light settings: Focus, energy, calm, and normal)	Educational performance in the classroom (cognition, motivation, and concentration)	(+) The focus setting helps students to settle in and concentrate much easier than any of the other lighting modes.
16.	Ljung, Sörqvist, and Hygge (2009)	Quantitative study	n = 1 (nine classrooms) pp = 187 pupils yr = 12–13 c = Sweden	Classroom noise (irrelevant speech in classrooms and road traffic noise adjacent to schools)	Children's learning (reading and mathematical performance)	(−) Road traffic noise was found to impair reading speed and basic mathematics. (0) No effect was found on reading comprehension or on mathematical reasoning. Irrelevant speech did not disrupt performance on any task.
17.	Riley and McGregor (2012)	Quantitative study	n = n.s. pp = 31 children yr = 9–10 c = USA	Effects of noise (noise vs. quiet) and speech style (plain vs. clear)	Word learning in typically developing school-age children	(+) Children who were trained in quiet learned to produce the word forms more accurately than those who were trained in noise. (−) Noise limits expressive vocabulary growth in children, reducing the quality of word form representation in the lexicon. Clear speech input can aid expressive vocabulary growth in children, even in noisy environments.

Table 3. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
18.	Ana, Shendell, Brown, and Sridhar (2009)	Quantitative study	n = 8 pp = 400 yr = above 14 years, secondary school c = Nigeria	Noise levels in classroom	Adverse noise-related health and learning effects	(–) Over 60% of respondents reported that vehicular traffic was a major source of noise, and over 70% complained of being disturbed by noise. Three schools reported tiredness, and one school lack of concentration, as the most prevalent noise-related health problems.
19.	Ljung, Sörqvist, Kjellberg, and Green (2011)	Quantitative study	n = n.s.; 1 pp = 20 adolescents from an upper secondary school class; 28 university students yr = 17–35 c = Sweden	Listening conditions in classroom (resulting from background noise and/or long reverberation time)	Learning (memory for spoken lectures)	(–) Poor listening conditions impair memory and learning, even if the conditions allow the listeners to hear what is said. Standards should be based on memory criteria instead of intelligibility criteria.
20.	Whitlock and Dodd (2008)	Quantitative study	n = n.s. pp = 18 children; 15 adults yr = 7–9½ (children) c = New Zealand	Noise level in classroom (e.g., reverberation time)	Children’s speech intelligibility in classroom (needs of children and adults for speech perception)	(–) When groups of children engage in ‘cooperative learning’ activities in the classroom, the “café effect” produces a rising activity noise level. Authors suggest the Lombard effect is responsible for this. Measurements show children are more susceptible to the effect. Existing design standards for reverberation time may not be appropriate to children’s speech intelligibility requirements.
21.	Muthu Shoba Mohan, and Rajagopal (2010)	Quantitative study	n = 25 schools (120 classrooms) pp = n.s. yr = 6–14 c = India	Range of external noise of school building: Schools located close to public roads (noisy-sites); schools located in housing sites; schools located in quiet zones	Learning environment of the children in schools in tropical climates (background noise in the classrooms where the windows and doors are kept open during class sessions, since no heating, ventilation, or air-conditioning systems are provided in any of the surveyed schools)	(–) Background noise in classrooms is influenced by the noise level of the zones where the schools are located. Opening windows may not be practicable for schools in tropical climates, where rooms with open windows and doors are realities. The intelligibility of speech in a classroom is influenced not only by the background noise, but also by other parameters like reverberation time, and the distance between the teacher and the students.

Table 3. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
22.	Kinnealey et al., (2012)	Mixed-method design	n = 1 licensed, nonprofit, private academic school for prekindergarten through 12th-grade students with severe communication disorders, including students diagnosed with autism pp = 4 male students yr = 13–20 c = USA	Modification of acoustic and lighting features of classroom (installation of sound-absorbing walls and halogen lighting system)	Attention and engagement of students with autism or dyspraxia	(+) The use of sound-absorbing walls and halogen lighting can benefit students with sensory hypersensitivity and improve their attention and engagement in the classroom. Results included increased frequency and stability of attending and engagement and improved classroom performance, comfort, and mood.

Note: n.s. = content “non specified” in the publication.

About the sample, 17 studies (77.3%) recruited only students as participants (of which six of primary schools, two of middle schools, four of both primary and middle school, four of post-middle school and one of unspecified age) and the remaining five studies sampled both students and teachers (22.7%).

As for the study design, different methodologies were used across the 22 papers of this cluster (see Table 1). In 19 studies (86.4%), effects of indoor environmental features were detected by quantitative methods (i.e., survey, experiment, and field studies), two studies (9%) used a mixed design (both quantitative and qualitative methods), and the remaining one study used qualitative methods (collection of the teachers' data).

As concerns the measures, 10 studies used objective measures (e.g., classroom ventilation rates, acoustic and lighting parameters, students' scores on standard tests), whereas three studies used one or more of the following types of self-report measures: Teachers' and/or students' evaluation of teaching/learning experiences, perceived satisfaction, thermal sensation/comfort, and so on. The remaining nine studies used both objective (especially to assess exposure conditions, in terms of role of acoustic and lighting features of the classroom environment) and self-report measures. The most studied outcome variable was students' learning, in terms of performance, ability, level of attention and concentration, followed by wellbeing in terms of health and comfort, and, finally, by students' and teachers' perceptions of physical environment. Regarding the countries, the studies were mostly (63.7%) conducted in Europe (eight) and US (six), while the other studies were conducted respectively in Asia (five), Australia and New Zealand (two), and Africa (one).

The overall findings show that 46.7% of the reviewed studies presented positive (+) results, 50% showed negative results (−), and 3.3% presented no changes (0).

Indeed, differently from the prior cluster that identified an equal number of qualitative and quantitative studies, the present cluster of studies was skewed toward the quantitative and experimental approach. This is probably due to past research traditions on the effects of physical attributes that are more prone to environmental assessments. Although this approach has some concrete advantages (e.g., identification of the variables, involvement of a greater number of participants, comparison between studies), on another hand, it overshadows important aspects. For instance, this line of research often investigates the effects of environmental features on "objective" variables such as learning outcomes and performance: Qualitative research would be likely to deepen the analysis on subjective users' wellness, experience of stress, or comfort. Moreover, most of the cited studies focused on a single physical characteristic of the indoor environment (e.g., noise, light, ventilation), leaving out important interactions between these features in a naturalistic setting and between indoor and outdoor or contextual variables.

In this vein, studies on multisensory integration (e.g., light color and temperature; [59]) could provide important suggestions for future research. Importantly, few studies explored the effects of indoor physical attributes (e.g., [60]) on pupils with special needs: Developing this line of research is crucial to design actual inclusive learning environments.

3.3. Effects of Classroom Design and Furniture on Students' and Teachers' Psychological Responses

Starting from 1307 total articles, this cluster identified 108 initial papers, but only 81 were reviewed due to duplicate publications. Twelve articles were finally included, of which three studies came from other clusters (Table 4).

Table 4. Studies on the effects of classroom design and furniture.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
1.	Benes, Finn, Sullivan, and Yan (2016)	Mixed-methods design, quantitative and qualitative (written survey and semi-structured interviews)	n = n.s. pp = 17 teachers yr = average age of 39.7 c = Massachusetts and New Hampshire (USA)	Possibility to move in the classroom (space and layout)	Teachers' perceptions about benefits of using movement in the classroom	(+) Teachers discussed that students enjoy moving in the classroom and that they use movement - to increase students' engagement with their academic content; - to give the students a break before returning to academic content; - to help students in refocusing; - to focus students and to improve learning; - to help students retain the information and increase their ability to learn and remember material.
2.	Durmuş (2016)	Qualitative study	n = n.s. pp = 48 elementary school teachers and 6 school administrators yr = n.s. c = Turkey	Features of physical environments, instructional technologies, materials	Participants' views on learning environments (requisites to enable learners to construct knowledge)	(-) Participants underlined the need for separate classrooms for each course; - Beside the seating arrangement, classroom sizes were criticized. There is no place for walking, lying and reading books or drawing, searching or creating a learning center (+) Teachers suggest decreasing the number of students in a classroom to create a place for free-time activities; - If the activities are conducted on carpet floor, the feeling of safe and comfortable learning environment leads to feeling of enthusiasm from their point of view; - Teachers also expressed that they need personal cabinets to hold exam papers.
3.	Liou, Marsh, and Antrop-Gonzalez (2016)	Qualitative study	n = 1 pp = n.s. students who had historically been marginalized in academic contexts yr = 11th- and 12th-graders c = California (USA)	Spatial arrangement of learning opportunities as manifestations of teachers' and students' expectations in learning contexts.	Spatial behaviors of teachers and students	(+) The spatial behaviors of students and teachers are greatly influenced by the expectations they had of each other, and by extension, the spatial arrangement of learning opportunities as manifestations of their expectations in learning contexts.

Table 4. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
4.	McAllister and Maguire (2012)	Qualitative approach	n = n.s. pp = Autism spectrum disorder (ASD) teaching staff yr = n.s. c = Northern Ireland	Utilization of a design kit to describe an ASD-friendly classroom layout	A better learning environment project	<p>(+) The use of modelling with the ASD Classroom Design Kit at an initial design phase encouraged the teachers to 'buy into' the design process.</p> <ul style="list-style-type: none"> - The teachers were able to share their ideas with the architects, and the architects got a valuable insight into <i>why</i> those choices were being made.
5.	Martins and Gaudiot (2012)	Qualitative study	n = 2 pp = deaf students and teachers yr = from kindergarten to middle school c = Brazil	Attended learning environment	Deaf students' perceptions about comfort in their learning environment (referring to lighting, acoustics, accessibility, visualization and detection, warning signs, furniture, and layout of the classroom)	<p>(+) To improve the learning environment for deaf students some suggestion are:</p> <ul style="list-style-type: none"> - Color signal system above the blackboard with a switch beside the teacher desk to alert about attention, danger, breaks, end of classes, etc.; - Layout in circle shape for classes with fewer students and in a steps audience shape for more students. If it is an inclusive class the deaf student should be in the second line, which allows him to see the reaction of the front students during the questions/answers, or when in front in diagonal, in relation to the class. In either case no obstacle should be between him and the teacher or interpreter and the blackboard; - The blackboard should be big enough to keep the information for enough time to be written by the deaf students; - Put corner concave mirrors so the students can see and follow his colleagues; - The furniture such as desks and chairs are separated to prevent dropping materials during sign language use; - Avoid sun glare in the blackboard and class with curtains or brise soleils outside; - Forecast the use of electronic material for visual explanation of the subjects, such as computers, overhead projector screens, etc.

Table 4. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
6.	Maheshwar and Jawalkar (2014)	Quantitative study	n = 2 elementary schools pp = 100 students (50 for each one) yr = 4–7 c = n.s.	Evaluation of existing school furniture and developed prototypes (e.g., with ideal school chairs' parameters for different physical dimensions of students)	Subjective comfort and satisfaction evaluation	(+) New designs are described as acceptable, economic, multi featured, and serving to the ergonomic requirements of kids in that age range. - The painting of such furniture with attractive colors, cartoons, and pictures would further make the design fascinating and admirable amongst the target population.
7.	Smith (2013)	Report	n = n.s. pp = n.s. yr = K–12 c = n.s.	Environmental design of classroom and building design factors	Student performance and learning	(+) Student academic performance is strongly influenced by the level of classroom and school building design quality. - Previous studies cited in the report have in fact showed that: - Chair design, air quality, and noise as primary classroom design factors needing improvement, and provided an estimate that poor classroom design and maintenance can lead to decrements of 10%–25% in student performance; - Classroom furniture properly designed for children improves on-task behavior, promotes better sitting and standing postures, reduces back pain and other musculoskeletal complaints, increases trunk muscle strength, and improves overall academic marks. - Another emerging furniture trend is a movement away from straight-row ranks of student desks to clustered or U-shaped desk arrangements that favor group discussion and cooperative learning
8.	Gonçalves and Arezes (2012)	Qualitative study	n = several pp = 20 children yr = second to fourth grade of first cycle of education c = Portugal	Type of furniture: (a) Traditional furniture (flat table and chair with 5° backward tilted); (b) with the use of a traditional chair (5° backward tilted) and table 12° tilted; (c) with a chair with seat 12° sloped forward and a table top 12° tilted.	Children's wellbeing (neck and back postures)	(+) The best posture for the trunk is achieved by using a combination of furniture with tilted tables and seats. - The school furniture should be designed to accommodate the natural resting position, in which - opposing muscles are well balanced. The resulting posture will tend to improve performance, efficiency, and children's wellbeing.

Table 4. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
9.	Woodcock, Woolner, and Benedyk (2009)	Case study (field study, interviews, observation, qualitative and quantitative approach)	n = n.s. pp = n.s. yr = primary school c = UK	Application of Hexagon-Spindle (H-S) model classroom design (that is, a low sensory room, stripped, and equipped with furniture and places that would enable individual, supervised, and joint working. A tailorable lighting system, full size display screen, movement area, and six basic learning modules were provided)	Benefits in children with special education needs, autistic spectrum disorder (e.g., time on task, or engaging in imitative behavior)	(−) A ‘one size fits all’ educational environment was not considered appropriate due to the potential wide range of needs that had to be accommodated. It is important to determine the range of tailor ability that had to be accommodated. (+) The room was positively viewed by all groups—children were willing to try new experiences and engage in social play. Two parents noted improvements in behavior and an increase in verbalization.
From other clusters:						
1.	Parnell and Procter (2011) B1	Qualitative study	n = 4 (two primary schools and two secondary schools) pp = Primary School A: 24 pupils, 1 teacher; Primary School B: 27 pupils, 1 teacher, 1 teaching assistant; Secondary School A: 25 pupils, 1 teacher; Secondary School B: 20 pupils, 1 teacher yr = 6–14 (students) c = UK	Flexibility in school design (e.g., in spatial design is represented by non-bounded, open space, moveable elements, independent structure and services).	Learning autonomy	(+) Once children are enabled to experience their learning environment as ‘flexible’ by changing it themselves, they are better able to self-direct their learning. - At the same time, autonomous learners and teachers are important in order to make viable changes to the environment. - Among the barriers that need to be overcome to enable such a form of flexibility are class sizes and structures, timetabling, the aspiration for still, quiet bodies during learning, a conditioning in some students to want to be ‘led,’ and the teacher’s own sense of self and authority.

Table 4. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
2.	Gislason (2010) B1	Qualitative study	n = 3 open-plan high schools pp = principals, teachers and students yr = n.s. c = USA	School's physical design—presence of pods in the advisory area (HSRA - High School for Recording Arts)	Participants' opinion about teaching and learning (HSRA)	(−) Group work and lecturing are not easily conducted in the pods because the corrugated dividers separate students into small, visually self-contained units. (+) Design of the pods and the layout of the building present definite challenges: Social behavior is facilitated by the advisory area's visual and acoustical openness, while surveillance is hindered by the dispersal of instructional space throughout the school and by heterogeneous scheduling patterns (−) While HSRA's design dovetails with the advisory system's spatial needs, the ongoing presence of traffic and noise places real pressure on the program.
3.	Aturupane, Glewwe, and Wisniewski (2013) B2	Quantitative study	n = 939, 140 pp = 16.383 (NEREC), 2653 (NEC) yr = primary school c = Sri-Lanka	School Quality (e.g., student desks, blackboards, computers, toilet, electricity)	Learning in primary schools—reading and math skills—and students' academic performance	(+) The only school physical facility or equipment variable with any significant impact is desks. - Students who have exercise books and attend schools with enough desks appear to learn more

Note: n.s. = content "non specified" in the publication.

As for the sample, five studies (42%) recruited participants from students (specifically, from elementary schools), three (25%) sampled staff (among teachers, school administrators, and other related staff), and the remaining four studies sampled both students and teachers (33%).

As regards the study design, a range of different methodologies were used amongst the 12 studies in the third cluster. In eight studies (about 66%) effects of spatial features (classroom design) and furniture were measured by qualitative methods (focus groups, informal interviews, observations, case studies, reports), two studies (about 17%) used quantitative methods (i.e., surveys and field studies) and the remaining two studies (about 17%) used a mixed design (both quantitative and qualitative methods).

Concerning the measures, 11 studies used self-reported measures (i.e., students' perception and satisfaction towards the learning environment, in terms of spatial evaluation of movement, furniture arrangement and room design, subjective comfort, wellbeing), whereas only one study (see [61]) used both objective and self-reported measures.

About the countries, four studies were conducted in Europe (two in England, one in Ireland, and one in Portugal), two studies were conducted in Asia (one in Turkey and one in Sri-Lanka), four studies were conducted in the American continent (three in USA and one in Brazil), and finally, two studies were conducted in a not specified country.

The overall findings illustrated that 75% of the reviewed studies presented positive (+) results, whereas the remaining 25% showed negative (−) results.

Overall, the research literature on this cluster has been definitely characterized by the predominance of qualitative data, collected through interviews (individual or group ones) or observations, or derived from the realization of case studies. The primacy of self-report measures as outcome variables is another distinctive feature of this cluster. The presence of studies addressing the needs of specific students' categories (in particular children from primary schools, but also deaf or autistic students) could be related to the fact that the spatial level of analysis of this cluster is more circumscribed and focal than the others, representing a sort of microsystem for the user, as highlighted by the multiplace approach (see [7,38,39]). In other words, the classroom environment being the most direct, central, and thus meaningful subsystem of the school environment in the experience of students and teachers, then this spatial level should be particularly cared for in order to respond to differential needs.

As for the previous clusters, it is quite difficult to make comparisons across studies, given the predominance of qualitative studies as well as the high variability in construct operationalization, sample size and characteristics, kinds of techniques and tools (often ad hoc ones, not previously validated). Future research should investigate the potential role of socio-demographic variables (e.g., gender) and socio-psychological dimensions (e.g., interpersonal distance, intra-group and inter-group dynamics, social norms) as potential moderators of the relationship between the "objective" classroom environment features and users' responses.

3.4. Effects of School Green Spaces or Outdoor Spaces on Students' and Teachers' Psychological Responses

Starting from a total of 1307 papers, this cluster identified 199 initial articles, 143 of which were reviewed due to duplicate publications. Twenty-four articles were finally included, one study of which came from another cluster (Table 5).

Table 5. Studies on the effects of school green spaces or outdoor spaces.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
1.	Yates and Sullivan (2017)	Qualitative study	n = 3 pp = 11 school staff and local members yr = Elementary, middle school, K–8 c = Southwest Montana (USA)	Development of school gardens and garden-based curriculum	Impact of school garden on the students and on the local community	(+) Positive impact of school garden on the students: Higher engagement in lessons, improved students' health.
2.	James and Williams (2017)	Qualitative study	n = 1 pp = 56 students yr = seventh and eighth grade c = Rocky Mountain West (USA)	Outdoor education experience	- Engagement in experiential outdoor education; - Perceived value of outdoor education	(+) A total of 79% of participants indicated that the outdoor education camp was worthwhile; involvement and love of learning also in disinterested and apathetic students; students' understanding was deepened more as their critical thinking skills were developed than in traditional lessons; enhanced sense of independence and responsibility.
3.	Christie, Beames, and Higgins (2016)	Qualitative study	n = 3 pp = 150 students and 10 teachers yr = 11–14 c = Scotland	Outdoor Journeys program (learning in an outdoor context, as school-grounds and local surroundings)	- Enjoyment of participants in activities; - Teachers' perspectives on the pupil experience and the learning process; - Teachers' willingness to implement outdoor program in the future.	(+) Some 89% of students enjoyed Outdoor Journeys; continual dialogue between the teachers and pupils as they worked together; two of three sample schools felt increased pupils' critical thinking skills; a teacher of one school reported that interpersonal skills were also developed.
4.	Gomboc (2016)	Qualitative study	n = n.s. pp = n.s. yr = 9 c = Slovenia	Teaching outdoor, in a natural environment (specifically, a park near the school)	- Learning of students; - Enjoyment of participants in outdoor activities, - Desire to learn in nature more often	(+) All the children said that they would like to learn in nature again; children explored actively the natural environment.
5.	Gehris, Gooze, and Whitaker (2015)	Qualitative study	n = n.s. pp = 37 teachers (20 lead and 17 assistant) volunteered to participate yr = n.s. c = Eastern Pennsylvania (USA)	Head Start program (movement experiences for about 1100 pre-school aged children, 40 classrooms)	Teachers' perceptions about the importance of movement for learning in children; - Best types of settings to support children's movement experiences	(+) Moving outdoors promotes learning; Contact with nature engages children's senses, which helps them to learn; children learn by being outside interacting with their community.

Table 5. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
6.	Sharpe (2014)	Qualitative study	n = 1 pp = 9 pupils, 2 charity staff, 2 teachers, 5 parents/carers yr = 10–11 (students) c = South East of England (UK)	Growing Together Schools Program (community gardening program)	- Learning; - Personal independence; - Changes in everyday practice; - Friendship	(+) The program promoted: Academic and social skills goals creating great fun and enjoyment in pupils; growth of pupils' self-confidence (personal independence); increased new friendship and teamwork.
7.	Mart, Alisinanoglu, and Kesicioğlu (2015)	Quantitative study	n = n.s. pp = 156 preschool teachers from 81 different cities yr = n.s. c = Turkey	Presence of school garden	- Use of school garden; - Perceived importance to take more places for garden activities in Preschool Education Programme	(+) School garden are used for play and for curricular activities (movement, science, art, language, music, math, literacy preparation).
8.	Bortolotti, Crudeli, and Ritscher (2014)	Case study descriptions and discussion	n = n.s. pp = about 40 in-service teachers yr = n.s. c = Italy	Training for teachers in outdoor learning (OL)	Teachers' perceptions about OL and training to practice it	(+) Teachers perceive positively the usefulness and impact of training in OL, as it tends to improve significantly the quality of relationship between themselves, children, families, and the out-of-doors settings; OL involves reflectivity and pragmatic points; OL fosters social and personal wellbeing.
9.	Dowdell, Graya, and Malone (2011)	Qualitative study	n = 2 early childhood centers pp = 12 children yr = 2–6 c = Sydney	Presence/absence of nature in outdoor environment of the center	Children's play, learning, and social behavior	(+) Natural environments support children's imaginative play, the development of positive relationships.
10.	Carrier, Tuguria, and Thomson (2013)	Mixed-methods research study, qualitative (interviews/observations) and quantitative (survey)	n = 2 pp = 49 students and teachers and school's principals yr = fifth grade classes of elementary school c = USA	Environmental and outdoor vs. traditional education (pre-post test)	Students' science knowledge, environmental attitudes, and outdoor comfort levels (QNT); views on science education and environmental issues (QLT)	(+) All students showed growth in science knowledge; significant differences were found with respect to students' environmental attitudes; (-) No significant differences were found for students' outdoor comfort level (pretest and posttest).

Table 5. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
11.	Borić and Škugor (2014)	Quantitative study	n = n.s. (12 classes) pp/yr = 319 students of elementary school c = Osijek (Croatia)	Research-based outdoor teaching (experimental group, E.G.) vs. lecture-based teaching (control group, C.G.)	Students' motivation, participation, and learning (knowledge, abilities, and skills)	(+) High motivation, satisfaction and eager participation in E.G.; also, problem-solving abilities and skills are significantly improved; group work and cooperative learning are lower in C.G.; (−) The level of students' reproductive knowledge remains the same in E.G.
12.	Flom, Johnson, Hubbard, and Reidt (2011)	Two case studies	n = n.s. pp = n.s. yr = primary level children; high school-level students c = USA	Outdoor problem-solving counseling program; participation to an extracurricular fishing club, especially for more disadvantaged students (for ethnicity, income, disability, and low involvement to school activities)	1) n° of discipline referrals; 2) student connectedness (interpersonal and coping skills; academic outcomes emphasized goals, time/task management, and problem solving; and outcomes related to careers addressed both career awareness and employability skills)	(+) Improvement of social relationships with peers and general reduction in discipline referral; high involvement in club activities, high inclusivity.
13.	Dhanapal and Lim (2013)	Mixed-methods research study, qualitative (observations) and quantitative (quiz test and survey questionnaire)	n = 1 pp = 34 students yr = third grade c = Malaysia	Type of learning (indoor vs. outdoor before)	Students' academic performance and students' point of views about the integration of both indoor and outdoor learning in science	(+) Indoor and outdoor learning complement each other in improving students' academic performance.
14.	Feille (2013)	Qualitative study	n = 1 public urban school and 1 small private school pp = 3 teachers yr = n.s. c = North Texas (USA)	Experience of learning to teach in the school-yard and school garden	- Teachers' reactions and feelings in garden and outdoor teaching; - Teachers' experience in garden education	(+) Garden education allows students to see things and make connections that teachers cannot provide them in the classroom; nature can provide intense experiences of learning, inspiring students' curiosity and intent to learn.
15.	Brockman, Jago, and Fox (2011)	Qualitative study	n = 4 primary schools pp = 77 yr = 10–11 c = Bristol (UK)	Children were provided with a definition of active play, which was "any activity which takes place outdoors in your own free time which isn't organized by an adult."	Children perceptions of active play (self-reported motivators, barriers, and facilitators)	(+) Easily-accessible green spaces were reported to be regularly used for active play.

Table 5. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
16.	Eick (2012)	Qualitative study	n = 1 pp = 1 teacher and her class (22 students) yr = third grade of elementary school c = (USA)	School's outdoor classroom and a nature-study approach	- Teacher's evaluation of outdoor approach; - Children's state test results in reading and grammar for meeting annual yearly progress	(+) Science and language arts connected to the outdoor classroom were a big motivator for lower achieving children, whose self-esteem was boosted through outdoor experiences; high-stakes test results affirmed this approach through comparable high reading scores to other third grade classrooms.
17.	Paisley, Furman, Sibthorp, and Gookin (2008)	Case study (survey, qualitative data)	n = n.s. (six different National Outdoor Leadership School—NOLS—branches) pp = 441 yr = average of 24.9 years c = USA	Participation to a NOLS course	Learning of six targets: Communication, leadership, small-group behavior, judgment in the outdoors, outdoor skills, and environmental awareness	(+) Interaction with the physical environment may facilitate creation of student-oriented mechanisms for learning; immersion in and interaction with the natural <i>and</i> social environments may have direct effects on learning for certain students.
18.	Carrier (2009)	Quantitative study	n = n.s. pp = 109 students yr = fourth and fifth grade c = USA	Experimental (schoolyard) and traditional (classroom) condition classes	Environmental (a) knowledge, (b) attitudes, (c) behaviors, and (d) comfort levels	(+) Gender differences in learning styles; boys demonstrated statistically significantly greater gain scores in the outdoor treatment group than in the traditional classroom curriculum for all four outcome variables. Boys also scored statistically significantly greater in the treatment group on attitudes and behaviors than did girls in that treatment group.
19.	Stan (2010)	Qualitative study	n = 14 school groups pp = n.s. school children, teachers and the center staff yr = 6–12 (students) c = South-East England (UK)	Control, power, orders, and instructions of facilitators in outdoor education	Learning experience of children	(+) When control was exercised over the pupils taking part in outdoor activities, this impacted on the pupils' learning experience in a negative way, since the desired learning outcomes did not appear to be achieved.
20.	Waters and Maynard (2010)	Qualitative study	N = 1 pp = n.s. students and teachers yr = 4–7 c = Wales (UK)	Visit at a local country park (having several natural elements) as part of an outdoor learning project	Learning and involvement	(+) Children often expressed their interest with awe and wonder; value of a natural space with multiple, flexible features for stimulating children's interest.
21.	Hanvey (2010)	Qualitative study	n = 1 pp = n.s. yr = 5 c = Texas (USA)	Utilization of an outdoor prop box	Learning and socialization and children's emotional responses	(+) Experience not only enabled the children to practice and extend academic skills they were learning indoors, but also enhanced their social skills; children adopted conflict resolution techniques when trouble arose and became responsible as they restored the prop box taking turns with the materials.

Table 5. Cont.

N.	Authors	Research Design	Participants: Number of Schools (n), Sample (pp), Ages (yr), Country (c)	Exposure Measure	Outcome Measure	Relevant Results
22.	Carrier (2009)	Qualitative study	n = 1 pp = 14 preservice teachers yr = n.s. c = USA	Outdoor field experiences teaching science lessons to elementary school-age students	Their feelings of efficacy in teaching science; recognition of the potential for using the outdoor setting to teach science; intent to include outdoor education with future students.	(+) Twelve of the 14 pp described students' enthusiasm; - Participants shared enthusiasm that seemed to initiate with the students and then spread to the preservice teachers; - All preservice teachers expressed some intent to use outdoor activities; - The preservice teachers' increased comfort in teaching science as a result of their field experiences emphasizes the power of modeling and the positive impact of their observing students' excitement about learning science.
23.	Lloyd and Gray (2014)	Field study (case study)	n = n.s. pp = n.s. Indigenous students and parents yr = primary school c = Australia	Outdoor education	Learning	(+) Partnerships with Indigenous locals in facilitating outdoor education experiences are an excellent way to invite community members into schools, their knowledge and practice in the outdoors being invaluable.
From other clusters:						
1.	Anthamatten, et al. (2011) B1	Quantitative study	n = 3 × 3 elementary schools (recently-constructed "Learning Landscapes" (LL) schoolyards/LL schoolyards with older construction/un-renovated schoolyards) pp = n.s. elementary school students yr = 6–11 c = USA	Schoolyard renovation program ("Learning Landscapes" (LL) program), time of participation to the renovation program	Children physical activity in the schoolyard (before school, during school recess, after school, and on weekends)	(+) Overall utilization was significantly higher at LL schools than at un-renovated schools for most observation periods. (−) Notably, LL renovation had no impact on girls' utilization on the weekends, although differences were observed for all other periods. There were no differences in rates of activity for any comparison. With the exception of the number of boys observed, there was no statistically significant difference in activity when recently constructed LL schools are compared to LL schools with older construction dates and there was no difference observed in comparisons of older LL with unrenovated sites.

Note: n.s. = content "non specified" in the publication.

Concerning the sample, seven studies (29%) recruited participants who were students (one of which was attending early childhood education, four of which were attending primary school, one from middle school, and, finally, one with a sample of primary school students and another sample of high school students), nine studies (38%) sampled staff (among teachers and/or school principals) and/or other local members (parents, careers, charity staff), and the remaining eight studies sampled both students and teachers (33%).

As regards the study design, a range of different methodologies were used. In 18 studies (76%), effects of the presence of school activities in outdoor education form were measured by using qualitative methods (multi case studies, field experiments, semi-structured individual/group interviews, observation, and focus groups), four studies (17%) used quantitative methods (survey, experimental, and quasi-experimental studies), and the remaining two studies (8%) used a mixed design (both quantitative and qualitative methods).

About the measures, all studies used self-report measures (i.e., students' and teachers' perception of impact of outdoor education on learning, involvement, and enjoyment of participants), six of these used also objective measures (i.e., science knowledge assessment, knowledge test scores, students' academic performance).

As for the countries, 50% of studies were conducted in North America, 33% of studies were conducted in Europe (three in England, one in Scotland, one in Wales, one in Slovenia, one in Italy, and one in Croatia), and the remaining 17% of studies were conducted in Australia (two) and Asia (two).

Most of the findings (89%) presented positive (+) results, whereas the remaining 11% showed negative (−) results. The most examined outcome variable was learning evaluation, which referred to both the physical activity and the outdoor teaching experience.

Overall, if compared to the previous ones, this cluster of studies fruitfully integrate different perspectives and methodologies, revealing a quite consistent pattern of results: The opportunity to use outdoor spaces and facilities for outdoor teaching proved to be positively related to a wide range of variables. Importantly, these outcomes are not exclusively referred to performance in curriculum activities but also to relevant social skills (e.g., positive relationships, friendship, independence, self-confidence). However, these results also underline some points that require more attention and indicate future avenues of research. First, as for the previous clusters, outcome variables related to the outdoor environment have been often assessed through ad hoc measures: Further studies should address this point trying to validate more reliable instruments. This would also facilitate the comparison between different studies and results, thus providing a more systematic picture of the phenomenon. Second, research should try to integrate the investigation on indoor features with that on outdoor variables. Indeed, the relation between indoor and outdoor environments (hallways, windows, French window opening into the garden) has been barely explored. Furthermore, future studies should focus attention on individual differences that are likely to moderate such effects, as gender, age, and specific needs.

4. Discussion

From the review of the 68 papers selected according to specific criteria, a total of 68% of articles presented positive results, while the other ones showed negative results (29.2%), or no change (2.8%). Specifically, findings were organized in four sections based on exposure variables, i.e., architectural building design and aesthetic features, indoor environmental features, classroom design, and school green spaces or outdoor spaces.

About the first research question concerning the influence on users of *school building/architectural design/aesthetic features*, research has focused on the different impacts of new, old, and renovated buildings on students' performance. Findings showed that the better the building design, the higher the students' performance [47,57], as well as an increased positive benefit on students' wellbeing [51]. However, a negative effect on students' attention and sense of privacy was reported in the presence of flexible learning environments characterized by open and transparent designs (e.g., interior windows

or open spaces [46]). Furthermore, regarding the adequate size of buildings, Slunjski [62] found that facilities should not be too large to foster the development of children's identities. According to this scholar, too many groups in a kindergarten make it difficult, or even impossible, for children to socialize and communicate with other children from the various groups, and such occurrence is also an obstacle to free movement of children throughout the facility. The learning space, indeed, becomes part of students' identity and, in turn, they become part of the place [63].

As for the second research question, about the association between the *indoor environmental features* of the school place and users' psychological responses, research outcomes illustrated the importance of features such as noise, ventilation, and lighting in enhancing the students' academic performance. Many of the studies have focused on the acoustic features, which are identified as a potential factor able to decrease attention and concentration. Specifically, school buildings close to main roads had a higher level of noise pollution, with a significant impact on students' and teachers' performance and comfort [52,64], impairing memory and learning [65], even though the extent of annoyance depends on the task (e.g., verbal tasks, and basic mathematics; [60,66]). Moreover, higher noise levels impeded the development of interaction and collaborative learning [67]. However, students' learning and concentration are also affected by lighting [68,69], and specifically natural light in classrooms was associated with both better health and better performance [70]. Finally, further factors showing a positive effect on short-term concentration and performance (e.g., logical thinking) are thermal comfort and ventilation [42,43].

As regards the third research question, about the effect on users of *classroom design/furniture*, research literature has showed the relevant role of the educational environment on students' performance and learning capacity. Furthermore, a classroom design with a flexible space promotes self-directed student learning [71,72] and teachers reported several benefits on students (i.e., increasing engagement with the addressed topics, retaining information, and increasing ability to learn and remember material [73]). Furniture (e.g., chairs) designed for children were also identified as features with a considerable impact [71]. Satisfaction, wellbeing, and comfort are triggered by ergonomic furniture painted with attractive colors and pictures [53], a well-equipped library, and a fitted blackboard [54].

Finally, about the fourth research question concerning the influence on users of *school green spaces/outdoor spaces*, studies have mainly focused on teachers' perceptions and students' learning in the outdoor learning experience. Indeed, school green spaces showed positive effects on students, both in terms of better health and higher engagement in lessons, improving critical thinking skills, problem-solving abilities, and enhancing sense of independence, motivation, and responsibility [44,74–76]. Outdoor lessons triggered students' desire to learn in a natural environment [77], also promoting children's imaginative play and the development of social positive relationships [78–80]. Furthermore, outdoor experience enhanced students' emotional responses [81]. According to Dhanapal and Lim [82], an integration of both indoor and outdoor learning is recommended in order to improve students' performance. Regarding teachers' perceptions, they positively underlined the impact of outdoor teaching, reporting a whole involvement of students' senses and resulting in an enhancement of students' learning [83,84]. Better social and personal wellbeing were also reported [85].

This analysis of the recent literature concerning the influence of design dimensions on school users' responses underlined a series of gaps and some inconsistencies that merit attention and are likely to open future avenues of research. One gap concerns the methodological domain. In fact, findings of this systematic review let emerge that quantitative research is poorly represented in two of the four clusters, i.e., *classroom design/furniture* and *school green spaces/outdoor spaces* (see also Table 1). Thus, there is a need for more quantitative evidence about the relationship between indoor/outdoor school settings and users' responses. The integration of qualitative and quantitative approaches and the use of more recent methodologies (e.g., based on virtual reality) could represent an added value for better understanding such relationships.

These new technologies, the integration of qualitative and quantitative methodologies, and of implicit and explicit measures could also be used to update the analyses of some processes and the impact of variables that have been widely explored in the past (e.g., the role of indoor environmental features such as noise, light, color) but narrowly analyzed in the decade considered in the present review. This might create a gap between the engineering, architecture, design advances, and our knowledge of the influences of such innovations on the users.

Future research should also focus on patterns that have been scarcely considered by prior studies. For instance, future research might explore how spatial features affect perceived control over the learning environment space on students' ability to have better control of their environment.

Finally, the present review also highlighted some inconsistencies detailed in previous sections. For instance, results related to school renovation or about the impact of noise on math performance are not clear-cut. These ambiguities might suggest the role of crucial moderator variables, such as interpersonal distance, compliance to social norms, and place identity, just to name a few. Thus, future research is called to explore the boundary conditions of such results and clarify better the mechanisms underlying the effects (see Figure 2).

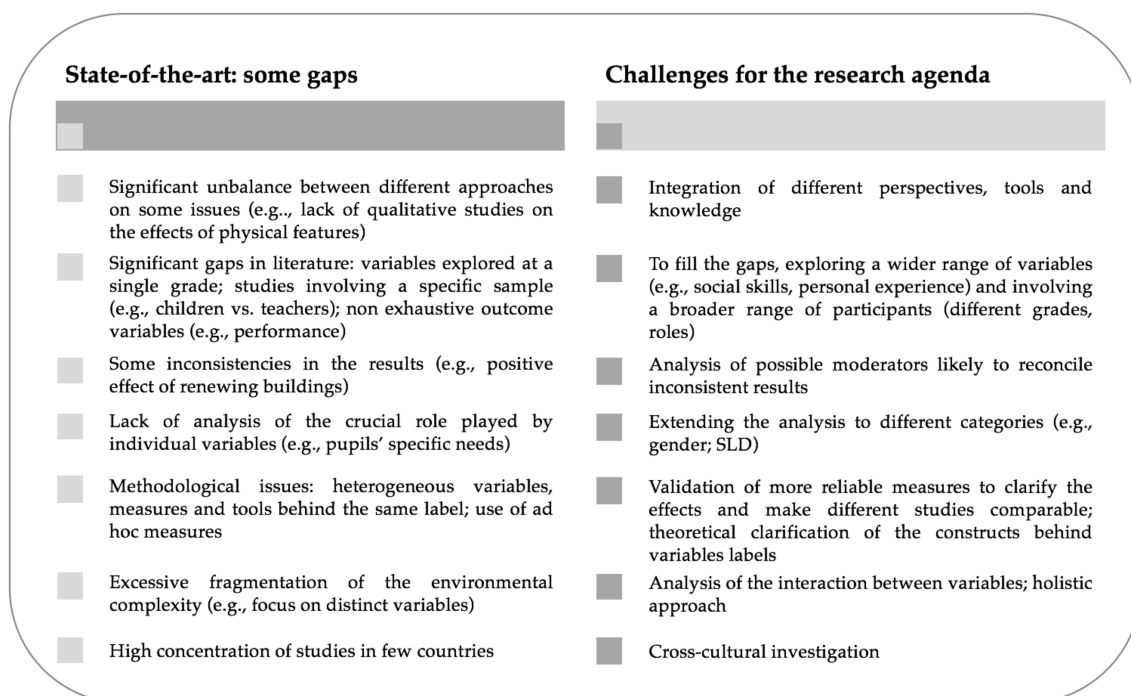


Figure 2. Summary of research gaps and challenges.

5. Conclusions

This systematic review is, to our knowledge, the first comprehensive systematic synthesis of recent evidence regarding the impact of different school environmental features on students' and staffs' responses, since other literature reviews on this topic (e.g., [86]) do not use the format of a systematic review. The only exception is represented by a systematic review about the effects of learning environments on students' learning outcomes, published in a technical report [87]. Nevertheless, it is worth noting that such a report, published after December 2017 (that is the time limit for our papers' selection), focused on a dimension (i.e., learning outcomes) that is more circumscribed than the broader one we considered.

Empirical findings of our review derive from studies conducted in countries with different educational systems and cultures. The overall results indicate that a series of school features, of both internal and external spaces, should be cared for, in order to fit with users' needs and improve learning experiences. In this regard, we need to consider that pupils from the age of five-years old spend at

least 6–8 h every day of the week in the school environment and apart from their homes—they spend more time at school than anywhere else.

Concerning the studies' research design, it is worth noting the prevalence of quantitative methods (such as experimental and quasi-experimental, field studies, and surveys) in studies related to the role of, respectively, architectural features and indoor environmental features in influencing users' responses. On the other hand, qualitative approaches (such as focus groups, informal interviews, observations, case studies) have been prominent in studies on the impact of, respectively, classroom design and furniture, and school green spaces, where the outcome variable was often learning evaluation. Future studies are required to fill the gaps, integrating qualitative and quantitative methods to study different aspects of learning environments (e.g., indoor and physical features)

As regards measurement issues, the use of self-report measures has been prevalent in almost all clusters, with the exception of studies on indoor environmental features, which mostly relied on objective measures (e.g., classroom ventilation rates, acoustic, and lighting parameters). In some studies, across all clusters, the combined use of both self-report and objective measures was chosen.

In sum, findings across different clusters highlighted the prominent role of a pleasant, warm, and flexible learning space in both influencing students' wellbeing and enhancing their academic marks, even though the presence of open spaces may also have a negative effect on students' attention and sense of privacy. In order to increase the level of comfort, satisfaction, and performance, several studies identified the importance of designing classrooms with charming colors, pictures, and ergonomic furniture, also paying attention to the levels of acoustic, thermal comfort, ventilation, and natural lighting. Furthermore, in order to improve students' learning and wellbeing, it should be recommended to have an integration of both indoor and outdoor learning. Indeed, green spaces showed relevant positive effects, both on scholastic and social aspects. However, future research should pay attention on individual variables (e.g., gender, age, and specific needs) that are likely to moderate such effects. Importantly, although it poses a critical methodological challenge, future research should focus attention not only on single variables but also on their interactions or co-occurrence in order to capture the high-level complexity of the phenomena.

Regarding the relationship between the school environment and place-related psychological patterns, only few studies have examined the effect of school design on place identity, whereas no studies have examined such effect on place attachment. Indeed, the substantial lack of research on these issues is rather surprising, given the importance for occupants' wellbeing of developing a positive interaction with a meaningful place, as the school is a place for both pupils and teachers. Future studies should then focus on that.

Finally, some limits of this systematic review need to be mentioned. Despite the attempt to get access to the relevant published literature through systematic research and the subsequent scanning of reference lists of articles, some publications may have been overlooked. A more complete set of keywords could have intercepted further research articles. We used as a search tool the integrated database EBSCOhost, which includes a considerable number of publishers and high-impact scientific journals, thus following the procedure of other systematic reviews (e.g., see [88,89]). However, we cannot exclude that some relevant papers have been missed. This should apply also for the choice of grounding on a division into four conceptual clusters: Such choice influenced the paper selection process, nevertheless it provided a systematic, structured, and consistent reading key for the analysis.

A further limitation of this review concerns the search process itself, which may not have allowed the identification of all studies showing the effects of the features of school environment on students' and teachers' responses, especially considering the pre-specified search criteria to include only English language full-text articles published in academic and scholarly peer-reviewed journals.

Overall, following an "evidence-based design" perspective [90], these research findings should inform the development of school design interventions, which are expected to promote positive effects on users' achievement, engagement, affective state, comfort and wellbeing, cognitive processes, social interactions, identification with the place, pro-social and pro-environmental behavior. In the long

term, the downstream results could be the reduction of the number of early-school leavers, increased wellbeing of pupils with specific learning disorders, promotion of positive class social interactions (e.g., reduction of bullying) and integration (e.g., reduction of ethnic prejudice), and prevention of teachers' burn-out. The recent trends suggest that "classic" old-style schools are likely to disappear to leave room to new learning environments in the future. Thus, the outcome of this review can be useful in the definition of guidelines for best practices that architects, education scientists, teachers, psychologists, policy makers, and members of the community could share within a "user-centered design" [2] view.

Author Contributions: Conceptualization, F.F., S.S., S.M., V.C., and V.T.; methodology, F.F., S.M., V.C., and S.S.; data curation, S.M. and V.C.; writing—original draft preparation, S.M.; writing—review and editing, S.M., V.C., F.F., S.S., and V.T.; supervision, F.F. and S.S.; project administration, F.F. and S.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Iscol@ Project (Autonomous Region of Sardinia, Italy, Regional Council Deliberation n. 10/15, 28/03/2014).

Conflicts of Interest: The authors declare no conflict of interest.

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