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Model of 21st century physical learning environment (MoPLE21)

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ABSTRACT

The physical learning environment is often considered to be a secondary element of education. Therefore, this study examined the following research questions: What role does the physical learning environment play in the educational process? How can we adapt the physical learning environment to 21 st century education? The present study analyzed behavioral models and reviewed 21 st century educational frameworks. Based on the findings, an ideal school environment model, called the MoPLE21, is presented and can be viewed online as an appendix of this paper at https://mople21.org. Our results show that the physical environment is an important and often underestimated factor in education, and an appropriately designed school environment can play a significant role in the 21 st century teaching and learning process. Finally, the MoPLE21 is discussed as an interdisciplinary tool for educational theorists and professionals for design, assessment, and everyday use in learning environments.

1. Introduction

The physical learning environment is most often considered to be of secondary importance in the education process. Nonetheless, increasing numbers of educators are becoming aware that the physical learning environment "defines the circumstances in which children enter the public arena," and "it is through the school architecture that ideas about collective life are communicated to children" (Van Den Driessche, 2007, p. 82). Researchers have remarked that a properly designed school building "helps teachers prepare young people for the demands of modern life, for flexibility, co-operation, thus making them competent navigators of an educational system that focuses on knowledge sharing and leaving room [sic] for inspiration" (Klawonn, 2010, p. 37).

Therefore, school buildings should not be viewed merely as the location of the education process or simply a safe place for pupils and teachers to learn and teach. Rather, the physical learning environment should represent the materialization of a society's ideas and values while creating optimal spaces for the teaching and learning process to occur (Burke & Grosvenor, 2008, p. 8). Thus, rather than being of secondary importance, school buildings are an essential aspect of education.

Hence, the idea underlying the present study was to improve the use of school architecture to support 21 st century education. This study examined the following research questions:

A What role does the physical learning environment play in the educational process?
B How can we adapt the physical learning environment to 21 st century education?

This article reviews the literature on the relationship between architecture and education. Based on this review, the authors

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developed the theoretical Model of 21 st Century Physical Learning Environment (MoPLE21), which is concerned with identifying optimal educational spaces. In sum, the MoPLE21 synthesizes education and architecture through psychological concepts. In the following sections the key issues in these three disciplines are introduced and the educational context for the MoPLE21 is presented.

2. Literature review

2.1. Educational background: toward change

Movements for reforming the ossified education system began to appear at the beginning of the 20th century known as "New Education" in Europe and "Progressive Education" in the USA. The child-centered approach of prominent educators of that movement (Montessori, Steiner, Dewey) emphasized criteria such as: imagination, aesthetics, critical thinking, experiential learning, collaboration, education for social responsibility, creativity, and personalized learning (Gidley, 2016, pp. 134–135). In the 1970s and 1980s "alternative education" emerged as a new wave of criticism of traditional mass education in Western world and part of Latin America (Gidley, 2016, p. 136). The concepts of that time covered a wide spectrum of educational views: from critical education focused on political awareness and social justice (Freire, 1970) to anarchist abandonment of the public schooling system (Illich, 1975). Unfortunately, some of the proposed valuable changes conceived during these two eras have never been widely implemented. Today we face a "third evolutionary wave" in education (Gidley, 2016, p. 137), and the need for a paradigm shift is clear (Kennedy, Latham, & Jacinto, 2016, p. 80). Kennedy et al. (2016) showed that the traditional model of education is widely criticized for its emphasis on academic knowledge, teacher-centered instruction, and its use of transmissive methods of knowledge transfer (Kennedy et al., 2016, pp. 79–82). Robinson (2010) pointed out that the "current system of education was designed, and conceived, and structured for a different age. It was conceived in the intellectual culture of the Enlightenment and in the economic circumstances of the Industrial Revolution," and it is no longer sufficient.

Many believe that the archaic education system cannot keep up with the current, rapidly changing era of "liquid modernity" (Bauman, 2013) and "digital natives" (Prensky, 2001). Recently published findings seem to confirm this opinion. A study by the Institute for the Future & Dell Technologies indicated that an estimated 85 percent of jobs in 2030 have not been invented yet (2017). The authors of that study predicted "in-the-moment learning will become the *modus operandi*, and the ability to gain new knowledge will be valued higher than the knowledge people already have" (p. 14). For this reason, Zhao (2014) lamented that China has already suffered from a lack of innovative talents. He argued that even though Chinese students perform the highest on the standardized Programme for International Student Assessment (PISA), making them a target of global admiration, this situation has effectively prevented reform of the Chinese education system (Zhao, 2014).

Recently, much attention has been paid to educational changes and themes such as developing 21 st century skills and competencies. These requisite abilities include creativity, critical thinking, divergent thinking, originality, and individualism (Piirto, 2011; Zhao, 2014); "high-level skills, knowledge, attitudes, and characteristics of self-directed and collaborative learning" (Griffin, McGaw, & Care, 2012, p. vi); and self-learning, networked learning, and lifelong learning (Davidson & Goldberg, 2009, pp. 26–35). Such 21 st century skills are essential in preparing young learners for the future.

Furthermore, many researchers believe that the learning environment plays a significant role in education (Cleveland & Fisher, 2014; Davies et al., 2013, pp. 84, 88; Higgins, Hall, Wall, Woolner, & McCaughey, 2005; Weinstein, 1979); at the same time however they emphasize the complexity of that relationship and the inconclusive evidence (Higgins et al., 2005; Woolner, Hall, Higgins, McCaughey, & Wall, 2007). Moreover, most have interpreted the learning environment as a social (Partnership for 21st Century Learning (P21) (2017b), pp. 8–9), institutional (National Advisory Committee on Creative and Cultural Education (NACCCE) (1999), pp. 138, 144), cultural (Mishra & Mehta, 2017, p. 15), or computer-based (Binkley et al., 2012, p. 32; Voogt & Pareja Roblin, 2012, p. 14) environment rather than a physical setting. Other studies have confirmed that the physical learning environment has not been widely regarded as being at the interaction level in the teaching and learning process. Moore (1989), pp. 2–5) specified three levels of learner-environment interaction: learner-content, learner-instructor, and learner-learner, while Bruno and Munoz (2010), p. 367) specified four levels: learner-teacher, learner-artefacts, learner-learning situation, and learner-community/classroom. However, none of these researchers deny the existence of other levels of interaction.

2.2. Psychological background: toward understanding

Lewin first wrote about the effects of the environment on human behavior. His famous equation $B = f(P,E)$, meaning that behavior is a function of a person in his or her environment (Lewin, 1936, p. 12), has become standard. Lewin understood the physical environment primarily as a context or structure for the cultural and social environment (Lewin, 1936, p. 20). Continuing Lewin's work, Barker developed Lewin's ideas further, shaping the foundations of environmental psychology. In his seminal work, Barker presented the concept of "behavior settings" (Barker, 1968): he provided quantitative evidence supporting the concept and the basic methodology for measuring the phenomenon. Barker's behavior setting theory was perceived from the beginning as an elegant explanation of the development of human personality, culture, and behavior as derivatives of both individual features and the influence of environment (Hall, 1969, p. 1186). Significantly, Barker was interested in the way that built environments affect human behaviors. He proved that the number of behavior settings does not depend on the size of a school. This was demonstrated through the more diverse roles and greater involvement of students in small high schools compared to large high schools (Barker & Gump, 1964).

The next step in studying the impact of the physical environment on human behavior was in the field of visual perception (Gibson,

1977, pp. 67–82, 1979). Gibson stated that the mind perceives environmental stimuli directly, with no cognitive processing. His research resulted in affordance theory. According to Gibson, "affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" (Gibson, 1979, p. 127). Affordance theory became as influential as it was controversial and has been widely discussed. Some researchers criticized Gibson's theory for its incompleteness and promotion of direct perception, which cannot explain cognitions of higher-order abstractions (Bickhard & Richie, 1983, p. 17, 64), or its lack of a representation layer (Bickhard & Campbell, 1996, p. 114). The definition of "affordance" itself was considered too simplistic and unclear (Norman, 2013, pp. 13–14, 309). A clarified definition of affordance in relation to perceptual information was later proposed by Gaver, in which he distinguished perceptible, hidden, and false affordances (Gaver, 1991).

More recent studies similarly divide affordances into subjective and objective types (Tillas, Vosgerau, Seuchter, & Caiani, 2017, p. 313), claim that affordances often invite or solicit action (Kaufer & Chemero, 2015; Withagen, Araújo, & de Poel, 2017), and explore the role of individual differences and emotions in response to affordances (Withagen, 2018).

The influence of the physical environment on human behavior is still studied in different contexts. Interestingly, confirmations have been found in the field of medicine. Noteworthy studies are those that have related obesity with one's relationship to their environment (Garfinkel-Castro, Kim, Hamidi, & Ewing, 2016). It has been argued that "obesity is linked to the built environment as a consequence of human behavior – in this case physical activity" (Garfinkel-Castro et al., 2016, p. 276). Other studies have reported similar findings concerning the correlation between built environments and mental health (Evans, 2003; Halpern, 2013). For example, Golembiewski (2016) argued that specific environments can trigger mental illnesses and foster mental oversensitivity.

2.3. Architectural background: toward interaction

The most influential theorist of modern architecture – Le Corbusier – believed that architecture had the potential to solve overpopulation, commuting, and infrastructure problems in interwar cities. However, it can also form "modern man" by meeting new universal needs and the "modern society" with new patterns of social life (Graham, 2016, pp. 77–114; von Moos, 2009, pp. 144, 147, 265, 316). Le Corbusier presented his concepts in his utopian project *Plan Voisin* (1925). It included the demolition of several of Paris's historical buildings and the construction of 60-story high-rise buildings that would house 3 million residents in a vertically constructed city. Le Corbusier's intention with this revolutionary urban design was to create a completely new way of inhabiting and using the city (Le Corbusier, 1987, p. 167). Le Corbusier saw human behavior as dependent on the built environment in which they live, stating that the architect "determines the various movements of our heart and of our understanding" (Le Corbusier, 1986, p. 1). However, his utopian ideas have not been widely accepted and can be labeled as "architectural determinism", according to the term coined in 1966 by sociologist Maurice Broady (Broady, 1966). With this term, Broady criticized the authoritarian belief that the built environment is the main or even sole factor in shaping social behaviors. Nevertheless, Broady admitted that architecture can limit and channel behavior in a predictable manner.

Today it would be naive to think that the physical environment is the only determinant of human behavior. Over time, views about the influence of the physical environment on human behaviors evolved toward the more liberal "architectural possibilism" (i.e., behavior can be limited but not restricted by the physical environment) and "architectural probabilism" (i.e., behavior can be predicted with a certain probability by the physical environment) (Strange & Banning, 2001).

A broader interdisciplinary understanding of architecture with a clearer approach to the social sciences began in the 1960s and 1970s. Urban planner Kevin Lynch stated that our visual perception of the urban environment plays a significant role in the everyday lives of individuals: for operating, moving, emotional security, and the intensity of experience (Lynch, 1960, pp. 4–5). Other prominent architectural theorists of that time argued in a similar tone that "architecture […] is based on a number of human instincts, on discoveries and experiences common to all of us at a very early stage in our lives" (Rasmussen, 1962, p. 14).

Rasmussen's position was further developed by architect Jan Gehl, best known for his work in Copenhagen. In the 1960s, he began to reconfigure the capital of Denmark from a city planned around cars to a city planned around people. Gehl's ideas about architecture, which were aimed at satisfying human needs and focused on peoples' behaviors (Gehl, 1987, 2010), became highly influential among the next generation of architects. His successes drew architects' attention to the large roles that sociology and psychology play in architectural design. Those roles have been recently confirmed by post-occupancy evaluation research of laboratory buildings. Its results have shown that proper architectural design (taking into account psychological and sociological aspects) can facilitate interactions among researchers, enhance collaboration, and improve efficiency (Goldstein, 2006).

In the context of designing physical learning environments, the leading figure is undoubtedly Dutch architect Herman Hertzberger. With his numerous publications on school architecture (Hertzberger, 1991, 1999, 2008; Hertzberger & de Swaan, 2009), he has shaped successive generations of architects in the spirit of humanism with a focus on school users, rather than on the school building itself. Hertzberger, in line with Gibson's theory, encouraged architects to design buildings that were open to interpretation, with many possible affordances to discover (Withagen, de Poel, Araújo, & Pepping, 2012, p. 254). His key project of the Delft Montessori School (1960–1966) became an icon and one of the few examples of school buildings corresponding significantly with the implemented educational program.

Table 1
Affordance distinction in relation to perceptual information (based on Gaver, 1991).

		Affordance	
		No	Yes
Perceptual Information	Yes	False Affordance	Perceptible Affordance
	No	Correct Rejection	Hidden Affordance

3. Materials and methods

3.1. Behavioral models

Various behavioral models have been advanced by researchers (Bandura, 1978, 2001; Bowers, 1973; Lewin, 1936). Table A1 in Appendix A provides a brief review of key behavioral models with brief explanations of each. The evolution of behavioral models provided a basis for creating the MoPLE21 at a later stage in this study.

3.2. Affordance distinction

For the MoPLE21, Gibson's theory of affordance was adopted, as well as the concept of dividing affordance distinction into four regions developed by Gaver. The original distinction formulated by Gaver is shown in Table 1.

3.3. Specifying 21 st century competencies

Since the late 1990s, new frameworks have emerged specifying new competencies and ca MoPLE21 at a later stage in this tegories for 21 st century education. Interestingly, although there are differences in categories according to different frameworks, convergence is observed at the level of single competencies (Voogt & Pareja Roblin, 2012, p. 315). The naming of categories is considered of secondary importance, as these are only the designators given by different authors. The specifying of individual 21 st century competencies is much more important. Table B1 in Appendix B lists six significant frameworks (i.e., review articles, books, and collective reports) that were used for further analysis. Based on the listed frameworks 29 competencies were specified and grouped into three categories: foundational knowledge (to know), cultural education (to value), and creative education (to act).

3.4. Elements of the physical learning environment

The term "learning environment" less frequently refers to the physical learning environment or space than to the social, psychological, or conceptual environment (Cleveland & Fisher, 2014, p. 1). In their comprehensive literature review, Cleveland and Fisher (2014) analyzed six methods of physical learning environment evaluation. They diagnosed the lack of pedagogical perspective as a gap in almost all presented approaches. Almost all methods are focused "on the physical features of the physical environment itself, rather than the alignment between spaces and desired educational practices, activities, and behaviors" (Cleveland & Fisher, 2014, p. 25). The only analyzed method that includes a pedagogical perspective is that proposed by Sanoff (2001).

However, individual elements of the physical learning environment with clear educational approaches were listed and grouped by Walden (2009), pp. 169–187). Walden's criteria supplemented with those of Sanoff and pilot studies conducted by the authors of the present study in several European schools formed the basis for the development of the MoPLE21 in a later stage of this study.

3.5. Theory and calculation

In all behavioral models mentioned in Table A1 in Appendix A, the E factor was interpreted mainly as the social environment (Kihlstrom, 2013, p. 793). Starting with Bandura (1978) reciprocal determinism model, further research was aimed at creating a model referring to the physical learning environment, such as the development of the site plan and architecture of the school building. Appendix C lists the next stages of creating the MoPLE21 with visual representations.

4. Results

As the final result of this research, the MoPLE21 was developed on the basis of the theory formulated in the previous section, *Theory and calculation*. The MoPLE21 organizes the relationships between education and the physical learning environment using environmental psychology. The MoPLE21 is presented as an online appendix at https://mople21.org. Figs. 1–3 present the basic elements of the website.

Fig. 1. The basic view of the online presentation of the MoPLE21. After clicking on the highlighted column, you can expand it. (In this case, column E3/SP is highlighted.) After hovering over the names of the rows and columns, an extension of the name with references appears.

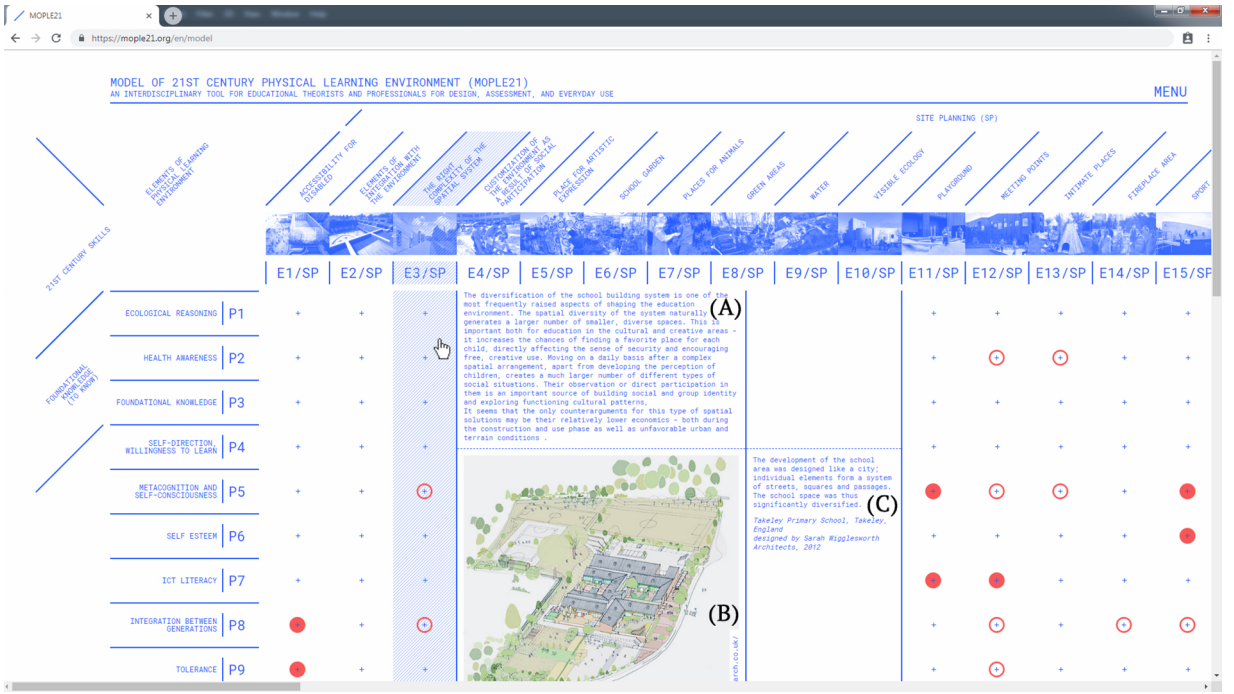

Fig. 2. After clicking on the selected column, a scrollable table appears. The table contains a description of the selected element of the environment and its possible use in the teaching and learning process (A). Below the description there are several examples illustrating the selected element (B) with brief comments (C).

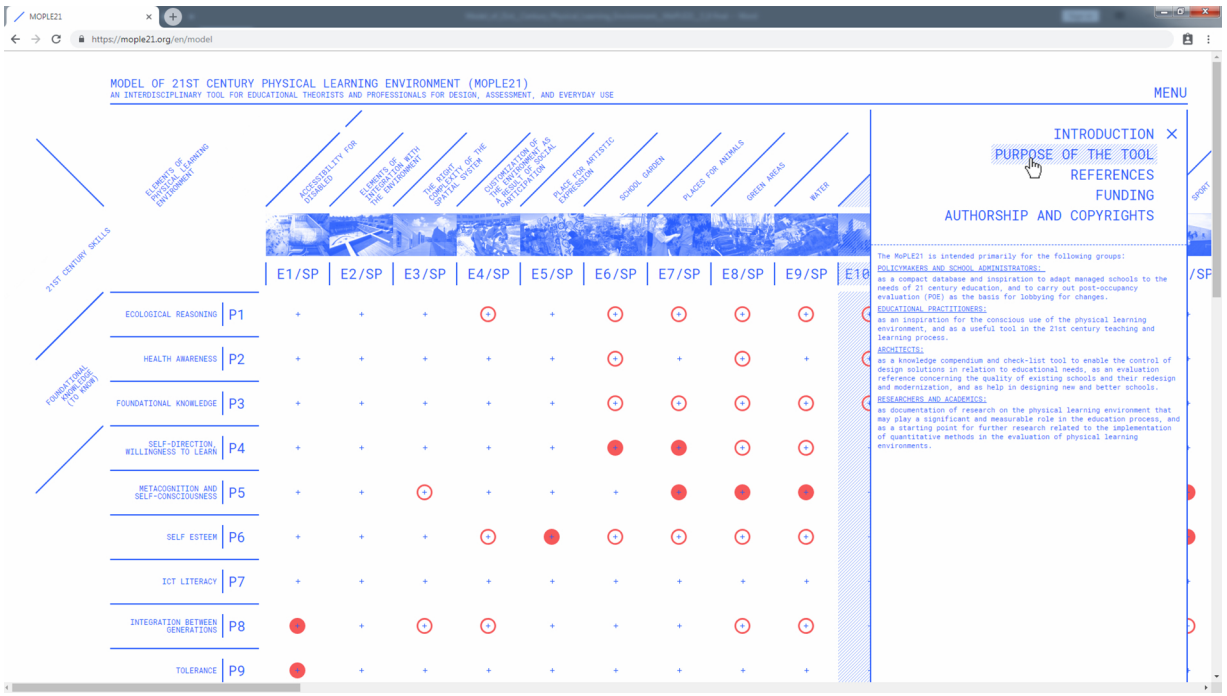

Fig. 3. Clicking on "MENU" reveals a section containing a short explanation of the research addressed to a wide audience. This section can be closed by clicking X.

5. Discussion and conclusions

The results of the present study led to the development of the MoPLE21. With environmental psychology as a connector, the MoPLE21 combines education and architecture. It presents the physical learning environment of schools as a possible interaction level in education.

The present study has also shown robust correlations between education, architecture, and psychology. Thus, interdisciplinary approaches are essential for shaping the physical educational environment and its appropriate use in the education process. However, in practice, interdisciplinary approaches have been applied in a very limited manner. For example, there is a conspicuous lack of psychology knowledge concerning human behavior among architects. On the other hand, teachers most often view the physical learning environment very objectively. Furthermore, environmental psychology is still marginalized within the field of psychology (Heft, 2013). Therefore, this work can be read as an attempt to restore the position of environmental psychology, interdisciplinary approaches, and the incentive to use knowledge from three related disciplines to advance educational practices.

The research questions posed at the beginning of this paper were thus answered as follows:

A The MoPLE21, with reference to behavioral models provided by environmental psychology, explains the influence of built environments on cognitive and personal factors. The MoPLE21 defines the role of the physical learning environment as a new interaction level in 21 st century education and presents its potential as a tool in the teaching and learning process.

B The MoPLE21 can be used as a simple tool for evaluating existing school environments or designing new ones, as it represents the ideal school environment. In cases of existing schools and schools still in the design process, it may be used for reference and comparison.

5.1. Study implications

At the theoretical level, the present study showed that the physical learning environment may be considered as the next interaction level in education. However, the MoPLE21 was also developed to serve both as a methodological and a practical tool. The systematization of 67 elements of the physical learning environment was designed for use by representatives of all educational sectors. It is intended primarily for the following groups:

A Researchers of education and other related disciplines: as documentation of research on the physical learning environment that may play a significant and measurable role in the education process; as an exposition of interdisciplinary research and thus an extension of fields of study in education; as a starting point for further research related to the implementation of quantitative methods in the evaluation of physical learning environments; and as a demonstration of the practical implementation of

environmental psychology and architecture in education.

B Policymakers and school administrators: as a compact database and inspiration to adapt managed schools to the needs of 21 century education, and to carry out post-occupancy evaluations (POE) as the basis for lobbying for changes.

C Educational practitioners: as an inspiration for the conscious use of the physical learning environment, and as a useful tool in the 21 st century teaching and learning process.

D Architects: as a knowledge compendium and check-list tool to enable the control of design solutions in relation to educational needs; as an evaluation reference concerning the quality of existing schools and their redesign and modernization; and as a resource in designing new and better schools.

5.2. Future research

The physical learning environment was not traditionally considered a level of interaction in the teaching and learning process. This article presents the theoretical concept of the physical learning environment as one of these interaction levels. However, further research is required. At this stage, the MoPLE21 represents a summary of the theoretical work, which requires some further empirical verification and development, and perhaps some corrections (see *Study Limitations* section). The MoPLE21 should be treated as a working version, which will be updated as the results of further research are obtained.

The MoPLE21 can also be used as a general sketch and starting point to exact original research studies on each of the 67 listed elements of the physical learning environment and its role in education. The first step would be a comparative analysis of the quality of the elements of selected schools with the MoPLE21, as well as an assessment of the impact of these environments on the teaching and learning process. Further adjustment of the elements and re-evaluation is required.

5.3. Study limitations: the ontological dilemma in design disciplines

The research is based on verified and widely accepted psychological concepts concerning the impact of the physical environment on human behavior and cognitive features. These concepts have been implemented in the theoretical MoPLE21. However, the MoPLE21 has a heuristic nature at the level of seeking and categorizing single behaviors. At this point, the research can be interpreted as revealing a well-known ontological dilemma in design disciplines.

Studies in the field of design disciplines are often maintained in the field of heuristic and qualitative research and criticized for being too subjective and intuitive. They are accused of having a lack of traditionally understood scientific proof, which is believed to be guaranteed in quantitative research. This is because many problems in the field of design cannot be tested in a laboratory context. On the other hand, conducting reliable experiments outside of the lab is often technically and economically impossible. For instance, “poor-quality housing appears to increase psychological distress, but methodological issues make it difficult to draw clear conclusions” (Evans, 2003, p. 536). This problem was also noticed by Dewey:

> As Dewey (1934) points out, the realist ontology of the natural sciences is no more useful for understanding design than it is for understanding human experience. The problem lies, according to Dewey, in the fact that the natural sciences are backward looking inasmuch as they seek to describe the way the world is, whereas the problem of design is to create an understanding of the way we might want the world to be. So instead of objective description it is necessary to place creative imagination and ways of seeing at the centre of our approach (Wright & McCarthy, 2005, pp. 12–13).

Conducted research can be partially confirmed by observations of school functioning, the education process, and children’s behavior. For example, creating and managing a school garden will allow children to develop practical skills in the field of cultivation, and with appropriate input from the teacher, a better understanding of healthy eating. Objectively, the MoPLE21 is based in that part on hypotheses. Although, from the heuristic point of view, single hypotheses often seem obvious, they may require direct confirmation and should thus be subject to further research.

Declaration of Competing Interest

None.

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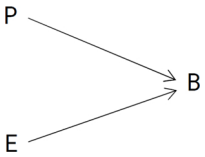
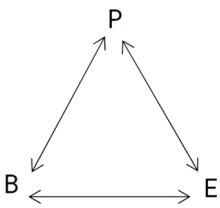
Appendix A

Table A1
Evolution in interpretation of behavioral model, forming the basis for MoPLE21.

Graphical representation of behavioral model	Short description
$B = f(P,E)$	Kurt Lewin's famous equation, meaning that behavior is a function of a person in his or her environment (Lewin, 1936, p. 12). It is a rather heuristic formula. "The comma (,) in the equation indicated that Lewin was open as to precisely how these factors combined" (Kihlstrom, 2013, p. 792). This is a unidirectional conception of interaction, specifying three factors: B – behavior P – cognitive and other person factors that can affect perceptions and actions E – external environment
	Interpretation of Lewin's equation by Bowers (based on Kihlstrom, 2013, p. 792), showing two independent determinants (P,E) and behavior (B) as their derivative. Relation is unidirectional.
	Bandura's reciprocal determinism model assumes the bidirectional interaction of behavioral factors, environmental factors, and internal personal factors: cognitive, affective, and biological (Bandura, 1978, p. 345, 2001, pp. 14–15). This model is the basis for Bandura's social learning theory.

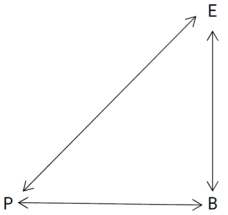
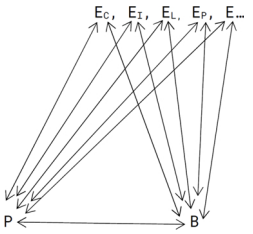
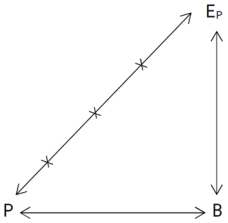
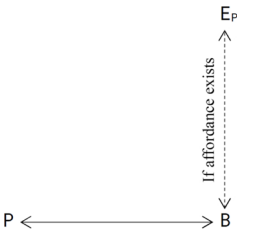
Appendix B

Table B1
Categories of 21 st century competencies according to different frameworks.

Framework reference, reference type	Specified categories of 21 st century competencies	Specified 21 st century competencies
(National Advisory Committee on Creative and Cultural Education (NACCCE, 1999) Report by representatives of the world of science, culture, and business.	Core and foundation subjects Cultural education Creative education	None listed, although many competencies are specified in the text.
(Kereluik, Mishra, Fahnoe, & Terry, 2013) A critical review of the 15 frameworks on 21 st century education.	Foundational knowledge (To know) Humanistic knowledge (To value) Meta knowledge (To act)	Each category has three subcategories. Single competencies are specified in nine tables.
(Gidley, 2016) A book on future education that author refers to as "postformal" in contrast to present-day "formal education."	Love – An evolutionary force Life – A sustaining force Wisdom – A creative force Voice – An empowering force	Twelve subcategories are defined. Competencies are specified in the text and tables.
(Partnership for 21st Century Learning (P21), 2017a) Report by a nonprofit organization (NPO) sponsored by the US Government, IT sector, and other NPOs	Learning and innovation skills Life and career skills Information, media, and technology skills	Each category has subcategories. Together there are around 60 individual competencies specified in all subcategories.
(Binkley et al., 2012) Book section	Ways of thinking Ways of working Tools for working Living in the world	Each category has two or three subcategories. Each subcategory is described with knowledge, skill, and attitude factors.
(Kennedy et al., 2016) The study was conducted on a large sample of 2000 teachers.	No grouping	Twenty-three categories of competencies are specified.

Appendix C

Table C1
Stages of development of the MoPLE21.

Theory	Visual representation
As a starting point, Bandura (1978) reciprocal determinism model was used. Bandura's model was rotated for convenience at further stages. At this stage: P is interpreted as internal Person/Cognition features B is interpreted as Behaviors E is interpreted as Learning Environment	
There were specified multiple levels of learning environment (based on Moore, 1989): E_C – Content E_I – Instructor E_L – Learner These levels were supplemented with two others: E_P – Physical Environment E… – other possible but unspecified interaction levels It obviously caused the multiplication of possible interactions. All interactions were marked with arrows.	
Further research was focused only on the physical environment (E_P) level. Only interactions at this level were extracted from the previous stage. P < ——— > E_P interaction was removed, similarly to Bowers' (1973) interpretation of Lewin's equation. E_P——— > P relation seems to represent architectural determinism, which is today considered arguable and unconfirmed (see *Architectural Background* section). Also P——— > E_P relation seems to have no applications when we interpret the E factor as the physical environment. People cannot directly influence their physical environment by willpower alone, without the mediation of a behavioral factor. (P < ——— > B) relation is possible and common. (P——— > B) relation can be interpreted as behaving according to Person/Cognition features. The reverse (B——— > P) relation can be interpreted as learning through behavior or by observing the behaviors of others.	
(E_P < ——— > B) relation is common but conditional. The necessary condition is the existence of affordance or possibility of introducing affordance. Because it is not always so, the relation is marked with a dashed line. (E_P ——— > B) represents exploitation of the environment using affordances. (e.g., I see a nice bench and decide to sit down.) The reverse relation (B——— > E_P) represents looking for environmental features to adapt for personal use. (e.g., I feel tired and I am looking for a place to sit down or adjust a space for sitting.)	
Based on the listed frameworks (see Appendix B) 29 competencies were specified and grouped into three categories. Categories were formed as combinations of categories (National Advisory Committee on Creative and Cultural Education (NACCCE, 1999) and frameworks (Kereluik et al., 2013). In the opinion of the authors of the present study, categories in these frameworks converge and most use readable naming.	P1 … P3 } FOUNDATIONAL KNOWLEDGE (TO KNOW) P4 … P18 } CULTURAL EDUCATION (TO VALUE) P19 … P29 } CREATIVE EDUCATION (TO ACT)

(*continued on next page*)

Table C1 (*continued*)

Theory	Visual representation
A total of 67 elements of the physical learning environment (E_P) were specified and divided into seven groups, based on elements listed by Walden (2009), pp. 169–187), supplemented with those by Sanoff (2001), and data provided by the pilot studies conducted by the authors of the present study in several European schools.	E1/SP … E19/SP } SITE PLAN E1/BE … E4/BE } BUILDING – EXTERIOR E1/IG … E19/IG } INTERIOR – GENERAL E1/EZ … E3/EZ } ENTRANCE ZONE E1/CR … E9/CR } CLASSROOMS OR OTHER EQUIVALENT SOLUTION E1/DS … E6/DS } DEDICATED SPACES E1/IC … E4/IC } INTERNAL CIRCULATION
Basic model was transformed into P–by– E_P matrix	E1/SP – E4/IC columns P1-P29 rows $\begin{bmatrix} B_{(1,1)} & B_{(1,2)} & B_{(1,3)} & \cdots \\ B_{(2,1)} & B_{(2,2)} & B_{(2,3)} & \cdots \\ B_{(3,1)} & B_{(3,2)} & B_{(3,3)} & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$
All behaviors in the matrix were categorized according to the typology of affordances by Gaver and marked with one of three signs.	⊕ For behaviors related to perceptible affordance ⊕ For behaviors related to hidden affordance + For no affordance (false affordance or correct rejection)

Appendix D

The Model of 21 st Century Physical Learning Environment (MoPLE21), which is supplementary material associated with this article, can be found in an online version at: https://mople21.org

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