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Original Research Article

Spatial Components of the Physical Environment and Their Impact on Deep Learning (A Systematic Review)*

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Abstract

Problem statement: This study adopts the deep learning approach to examine how the physical environment affects learning. From a cognitive perspective, deep learning encompasses a wide range of learning-related issues—from thinking to action—and therefore plays a significant role among modern learning approaches. It has also contributed to the integration of diverse research in cognitive science and neuroscience on learning.

Research objective: Aiming to connect the fields of cognitive science and learning space design, this study identifies the spatial components of the physical environment and analyzes how they influence deep learning. Accordingly, the research question is: What are the spatial components that influence deep learning, and how do they contribute to its enhancement?

Research method: First, to approach the subject of deep learning and extract the components related to the physical environment, an exploratory analysis of the literature and theoretical foundations was conducted. Then, a systematic review was employed to identify and categorize the spatial components of the physical environment. These findings were refined and completed using the snowball sampling method from selected studies.

Conclusion: The influence of spatial components on deep learning can be analyzed through types of student engagement and domains of mental functioning. This demonstrates both direct effects—via cognitive, emotional, and behavioral engagement processes—and indirect effects—via domains of mental functioning including perception, cognition, emotion, and action. Spatial components were also categorized into two dimensions: functional and physical. Functional components were more frequently addressed in previous studies due to their role in learning activities. The effects of these components were mainly discussed in relation to types of engagement, while physical components were considered more important in terms of their influence on domains of mental functioning.

Keywords: *Physical learning environment; Spatial components; Deep learning; Student engagement; Domains of mental functioning.*

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Introduction and Problem Statement

In recent decades, the design of new learning environments has become a major concern for educational designers and professionals in the field of teaching and learning. This period is often referred to as a transition from traditional, teacher-centered environments to innovative and learner-centered learning environments (Mahat & Emery, 2024; Fullan et al., 2018; Byers, Imms et al., 2018; Blackmore et al., 2012; Cleveland & Fisher, 2014). With the growing demand for such environments, understanding the relationship between contemporary learning approaches and the characteristics of learning spaces has gained increasing importance, leading to a shift in the way learning spaces are designed.

Among the emerging learning approaches, deep learning has recently played a significant role in addressing various theoretical and practical issues in educational psychology, cognitive psychology, neuroscience, and artificial intelligence. As a result, the concern for authentic learning that has a meaningful impact on individual and social life has become increasingly emphasized (Fullan et al., 2018). Over the past two decades, quantitative studies on the architecture of new schools—particularly those based on open and flexible spatial concepts—have reported improved learning outcomes for students (Barrett et al., 2015; Byers et al., 2014; Murphy, 2020). However, research that utilizes 21st-century learning theories—particularly deep learning—and influences components as dependent variables remain limited in number, although their importance has been widely acknowledged (Mahat & Imms, 2021).

Despite growing attention to deep learning in recent years, especially in relation to various topics (He & Hu, 2022), a comprehensive review of the existing literature that analyzes components and outcomes related to both the physical learning environment and deep learning is still lacking. Therefore, to explore how the physical environment contributes to deep learning, it is essential to identify the relevant spatial components. Given the conceptual complexity of deep learning, a comprehensive analysis of the literature is needed to identify the environmental components that influence it and to clarify the scope, dimensions, and results of previous findings.

Accordingly, this study aims to examine the relationship between the spatial components of the physical environment and deep learning. It conducts a systematic review of previous research to identify and introduce spatial components that contribute to the enhancement of deep learning. Based on this aim, the main research question is as follows:

What are the spatial components that affect deep learning, and how do they contribute to its improvement?

Theoretical Foundations

• Physical learning environment

According to Gibson's theory of affordances, the impact of the environment on human behavior is based on the affordances of the environment, which includes the physical characteristics of the environment as well as other material and immaterial features. These affordances represent the available resources that are usable by humans and play a role in their learning (Lang, 1978). The environment, in addition to its impact on the functional domains of the mind, provides opportunities for behavior and activities. It comprises a range of causes and various resources for action available to individuals (Withagen et al., 2012).

To define the physical learning environment, it is essential to examine the learning environment and its various dimensions. In contemporary learning environments with innovative and active approaches, which are introduced as facilitators for various student activities, the physical environment must meet the diverse needs associated with students' activities to integrate with the curriculum (Tanner, 2000). Bloom (1964) considers the learning environment as the external conditions, forces, and stimuli that challenge the individual. These forces may include physical, social, cognitive, and emotional conditions. Fraser et al. (1986) view educational environments as socio-psychological spaces that play a crucial role in learning.

In another definition, Nair and Fielding, in their book *The Language of School Design*, introduce learning environments as having spatial, behavioral, psychological, and physiological dimensions (Nair & Fielding, 2005), emphasizing

the simultaneous relationship between spatial components of the physical environment and the behavioral, psychological, and physiological aspects. Additionally, in another definition, the learning environment includes all physical, psychological, emotional, cultural, and social conditions and resources that impact the growth and development of the learner (Mohammadi & Mohammadi, 2013).

In a general view, without considering the various theoretical approaches to learning, the physical learning environment is recognized as one of the dimensions of the learning environment and a factor influencing the learning process and its outcomes. In a model presented by Phillips et al. (2010) to provide a conceptual framework for explaining the relationship between the learning environment, the learning process, and learning outcomes, the learning environment is defined as the setting in which students work. Its characteristics include the physical attributes of the environment, educational programs, and the individual program of each student. According to the model, learning processes refer to all cognitive activities that contribute to learning, as well as the way these activities are carried out, focusing on what students have done. Learning outcomes, on the other hand, refer to the skills that students can acquire as a result of their participation in a course.

As shown in Fig. 1, the described relationship in the model is based on the interaction between the teacher and the student. The teacher’s role is facilitative in the learning process, while the student’s role is to engage in the learning process. The learning environment facilitates learning processes, which in turn lead to learning outcomes. These learning outcomes then inform further decision-making and the determination of the boundaries of the learning environment.

Based on the approach of this study, which is focused on deep learning, the physical learning environment refers to one that impacts the deep learning process. Additionally, in relation to the learner, the way the physical environment influences the psychological, behavioral, social, and physiological aspects is significant. Since the physical environment includes both natural and artificial dimensions, which are related to spatial and natural components such as light, temperature, humidity, and sound, this study specifically focuses on the artificial environment from the perspective of its spatial components.

- The deep learning approach and its influencing processes

Among the three major learning theories—behaviorism, cognitivism, and constructivism—the deep learning approach aligns most closely with constructivism. According to the constructivist perspective, students actively seek connections between concepts and interpret new knowledge through the lens of their prior knowledge and experiences. At this level of learning, skills such as analytical and critical thinking occur, in which the learner engages with the intention of understanding and searching for meaning. Learning also occurs with interest in the subject and with the learner’s commitment and dedication (Hall et al., 2004; Biggs, 1987; Biggs & Moore, 1993; Beattie et al., 1997; Booth et al., 1999; Prosser & Trigwell, 1999).

Accordingly, deep learning is commonly defined as an active, logical, and effective approach to meaningful learning (Zhao, 2015). In this approach, students are inclined to participate actively in the learning process and guide their learning through their own perception. They engage in constructing knowledge by drawing

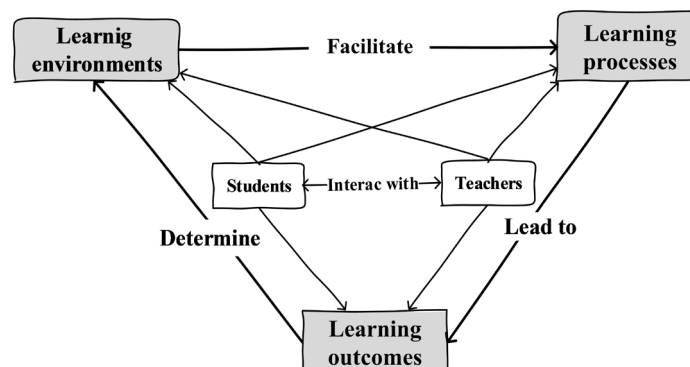


Fig. 1. The LEPO model: The relationships between the learning environment, learning process, and learning outcomes. Source: Phillips et al., 2010.

on personal experience and connecting various facts, deriving enjoyment from the process of discovery (Dejene et al., 2018). Moreover, students who adopt a deep learning approach are typically intrinsically motivated, viewing learning as a personal necessity driven by their own curiosity (Everaert et al., 2017; Biggs, 1987). It is also important to note that, like constructivism, the deep learning approach is learner-centered, emphasizing the learner’s interaction with both the social and physical dimensions of the learning environment. Studies have shown that among various learning approaches, learner-centered models—designed to encourage students to use critical thinking skills and engage directly with information—promote deeper and more significant levels of understanding, leading to greater efficiency and improved academic outcomes (Fink, 2003; Floyd et al., 2009; Majeski & Stover, 2007).

- Types of student engagement in learning activities

In examining the components that influence deep learning, one of the key concepts is student engagement, which has been a focus of learning theories for several decades (Chickering & Gamson, 1987). One of the earliest theorists to highlight the importance of student participation in the learning process was Astin (1984). In his theory of student involvement, he argued that learning outcomes depend on the amount of physical and psychological energy that students invest in their educational experience. According to him, this occurs when students participate in appropriate educational activities both inside and outside the classroom (ibid.). This perspective was further developed in the 1980s and 1990s by Marton & Saljo (1976, 1997), who formally introduced the concepts of deep learning and surface learning. Their early work is often credited as the origin of the term “deep learning.”

Engagement refers to the active involvement of an individual in a task (Christenson et al., 2012). In learning environments, it denotes students’ active participation in learning activities, acting as a starting point for the learning process that eventually leads to educational outcomes (Jang et al., 2012; Ladd & Dinella, 2009; Skinner et al., 2009). It’s important to note that students do not engage in “learning” per se; rather, they engage in tasks, activities, and experiences that facilitate learning.

In other words, engagement can be interpreted as the extent to which an instructional program or task holds meaning and value for students, captures their attention, and fosters a sense of commitment toward tasks and activities—so much so that they pursue them with interest and persistence (Bayramnejad et al., 2021; Schlechty, 2005). Since student engagement is an inclusive concept encompassing various aspects, efforts to operationalize and measure it have led to the identification of three types of engagement: behavioral, emotional (or social-psychological), and cognitive. As shown in Fig. 2, these are considered components of a multidimensional construct, comprising three distinct yet interrelated and mutually supportive pathways toward educational outcomes (Christenson et al., 2012; Fredricks et al., 2004; Skinner et al., 2009).

Behavioral engagement reflects the quality of active learning, as it involves observable behaviors such as active participation and collaboration with peers (Fredricks et al., 2004; Bryson & Hand, 2007). Some scholars have highlighted additional aspects of behavioral engagement, including rule compliance, participation in learning activities, and asking questions (Kahu, 2013).

Emotional engagement includes the development and expression of various attitudes, interests, values, feelings, and also a sense of belonging or attachment during learning activities (Fredricks et al., 2004). Emotional engagement is often associated with the presence of positive feelings during the activity, such as interest and enjoyment, and the absence of negative emotions like anxiety (Bandura, 2006).

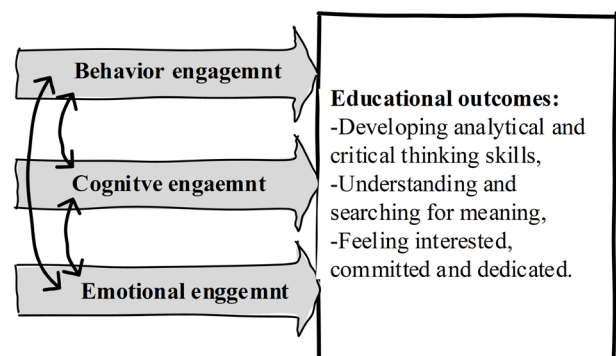


Fig.2. The interrelationship between behavioral, cognitive, and emotional engagement. Source: Authors based on Reeve, 2013; Hall et al., 2004; Biggs, 1987; Biggs & Moore, 1993; Beattie et al., 1997; Booth et al., 1999; Prosser & Trigwell, 1999.

Cognitive engagement in the classroom can be described as a psychological state in which students invest considerable effort to truly understand a subject, persisting in study over extended periods (Rotgans & Schmidt, 2011). It is characterized by motivated and effortful work, active curiosity, and the use of critical thinking and knowledge-construction strategies. Cognitive engagement reflects how strategically students strive to employ deep and complex learning strategies rather than surface-level ones—for example, using elaboration instead of rote memorization (Fredricks et al., 2004).

Cognitive engagement becomes evident in learning environments where students are encouraged to engage in problem-solving rather than passively receiving information through direct instruction. This includes students' flexibility in approaching problems, preference for challenging tasks, and a constructive response to failure. In such settings, students invest in learning for the sake of understanding, which is accompanied by motivational goals (Llorens et al., 2007; Boekaerts et al., 2000; Zimmerman, 1990; Connell & Wellborn, 1991). It is important to note that cognitive engagement goes beyond behavioral engagement, as it involves the deep learning of concepts and skills (Fredricks et al., 2004).

- Domains of mental functioning

In addition to the types of engagement, cognitive functions also influence deep learning. Studying cognitive functioning in learning and the services provided through it has been identified as valuable knowledge for improving the quality of deep learning (Pearson & Harvey, 2013). Among the various cognitive functions, the skills required for regulating and controlling behavior while applying different learning strategies are referred to as executive functions. Executive functions include essential skills for academic and professional success, personal development, and cognitive and social growth (Amunts et al., 2020; Ardila, 2008; Diamond, 2013; Nejati, 2010; Ghaemi et al., 2021).

One of the most comprehensive models representing executive functions is McCloskey's hierarchical model, which is considered one of the most optimal frameworks in cognitive science for explaining how the brain-mind functions in relation to learning. This model is based on

extensive conceptual and empirical findings from experts across various fields of neuroscience and educational psychology. Moreover, it not only aids in identifying and selecting the components influencing deep learning but also clarifies the developmental sequence of these components across different age groups (Ghaemi et al., 2021; McCloskey et al., 2009; Talkhabi et al., 2020).

Executive functions in McCloskey's model include thirty-one components, which represent the skills and abilities required for effective executive functioning across five levels, tailored to different age groups. Each level reflects different skills such as perception and reception, attention and memory, behavior organization, inhibition, flexibility, and others. Among the mentioned levels, the self-regulation level represents the most crucial skills for learning and deepening it. This level consists of twenty-three skills, each guiding specific functions. These skills are grouped into clusters based on their similarities, including attention, memory management, engagement, monitoring and adjustment, efficient performance, reflective inquiry, and problem-solving (Ghaemi et al., 2021; McCloskey, 2016; McCloskey & Perkins, 2016).

An important point in this model is that all executive functions are dependent on four domains of mental functioning: perception, cognition, emotion, and action. The difference lies in the fact that their level of engagement may vary in different situations. To enhance deep learning and strengthen various forms of engagement, opportunities should be provided to nurture executive functions in all four domains. However, not all of them are necessarily activated equally (McCloskey et al., 2009; Ghaemi et al., 2021; Talkhabi et al., 2020) (Fig. 3).

In this model, perception refers to the executive control of inputs, including external (sensory) and internal (representation) stimuli. Cognition refers to the executive control of thinking and its processes. Emotion refers to the executive control of feelings and emotional processes, while action refers to the executive control of outputs, including behaviors in the external world and the storage and retrieval of internal representations. In McCloskey's model, in addition to functional domains, the roles of relationships and social interactions, the physical environment, and culture are also considered. These are

introduced within four arenas: intrapersonal, interpersonal, environmental, and symbolic systems. These arenas serve as opportunities and contexts for enhancing and developing executive skills (Talkhabi et al., 2020).

The intrapersonal arena refers to an individual’s engagement with themselves, specifically how their perceptions, feelings, thoughts, and actions in relation to themselves are shaped. The overall outcome of effective involvement in the intrapersonal executive functions is the empowerment of the capacity to control one’s perceptions, feelings, thoughts, and actions in relation to oneself, which equates to self-control and personal discipline.

The interpersonal arena pertains to an individual’s engagement with others, i.e., how their perceptions, feelings, thoughts, and actions in relation to others are formed. The overall result of effective involvement in interpersonal executive functions is the ability to interact appropriately with others as the situation demands.

The symbolic systems arena refers to human-designed symbolic systems centered around culture, which are used to improve communication and enhance the capacity for cognitive processing. These systems include language, mathematics, and other logical systems, as well as related informational media such as words, numbers, shapes, charts, computer programs, and similar tools.

The environmental arena involves an individual’s engagement with the physical environment, including both natural and human-made elements of the world, i.e., their perceptions, feelings, thoughts, and actions in relation

to the surrounding environment. From the perspective of executive functions, this arena is where control processes are directed outward to regulate and control an individual’s perceptions, feelings, thoughts, and actions in relation to their environment (McCloskey et al., 2009).

The aforementioned arenas represent various dimensions of the learning environment, including psychological, social, cultural, behavioral, and physical aspects, as previously discussed (Nair & Fielding, 2005; Mohammadi & Mohammadi, 2013; Fraser et al., 1986). According to the McCloskey model, the interrelation among these dimensions can be analyzed and understood through the domains of mental functioning.

Methodology

This research was conducted through a comparative analysis and systematic review approach in three steps:

In the first step, using the existing theoretical foundations and aiming to approach the topic of identifying the components influencing the physical environment on deep learning and examining how they affect it, theories from educational psychology and cognitive psychology were used to identify the processes that enhance deep learning and their components. A model illustrating how the physical environment influences deep learning was then proposed.

In the second step, to answer the research question, a systematic review of studies was conducted following the guidelines of Creswell. The process involved three stages: search strategy design, selection of relevant studies, and data extraction and synthesis. Based on the search strategy for research articles, reviews, and doctoral theses, data were retrieved from five international databases¹ and two national databases² within the last ten years. The selection of articles was based on the question: Which spatial components of the physical environment affect the components of deep learning?

In the conducted search, the selection of keywords was based on the two main areas of the research, and efforts were made to avoid restricting them as much as possible to extract more components from the studies. The search keywords included terms such as physical environment, built environment, learning space, educational space, school, and deep learning, excluding the term “machine

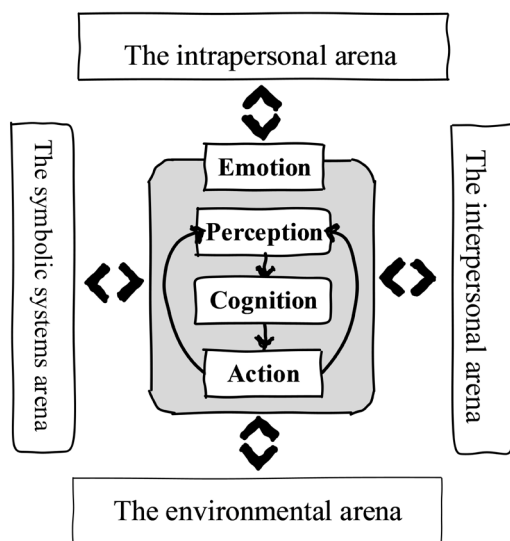


Fig. 3. The relationship between domains and areas affecting executive functions. Source: Authors based on McCloskey et al., 2009.

learning.” Among the foreign sources, only English-language sources were selected.

In the first stage of the search, 1,435 international studies and 63 national studies were found. Based on a review of their titles, 122 international studies and 10 national studies were selected. After studying their abstracts, 15 studies, including 11 international and 4 national studies, were chosen for the final selection. By reviewing the selected studies, some of the studies' sources that met the preliminary criteria for selection were identified, and through the snowball sampling method, the selected studies were further expanded and chosen for final analysis (Table 1). In this phase, after extracting the components of the physical environment and introducing its spatial components, they were categorized based on theoretical foundations related to the concept of space in architecture and the theories of key figures in the field.

In the final step, the model presented in the previous phase was completed based on the classification of spatial components and their impact on deep learning, and an evaluation of the research findings and gaps in the existing studies was presented.

As can be seen, among the studies, the constructivist perspective in active and learner-centered learning environments is the common theoretical framework in all the selected studies, which indicates their connection with the deep learning approach. The various titles introduced for innovative, active, informal, intelligent, and healing learning environments as conceptual frameworks of learning environments, and the examination of the physical environment characteristics in them from different dimensions, are also influenced by the quality outlined in their theoretical foundation.

Discussion: The Impact of Physical Environment Components on Deep Learning

Based on what was discussed regarding the relationship between the learning environment and its impact on learning processes and outcomes in the model by Phillips et al. (2010), the effect of the physical environment on deep learning can be examined from two aspects. First, the types of behavioral, emotional, and cognitive engagement in learning activities, reflect the active and comprehensive

involvement of the learner in learning activities. Second, the types of cognitive functional domains in the learning process, which indicate the mental capabilities in the areas of perception, cognition, emotion, and action, are aimed at deepening understanding and learning. The types of engagement reflect processes during the learning activity, while the types of cognitive domains represent processes related to the mind in learning that lead to engagement in the learning process.

As mentioned, the physical environment in new learning environments with innovative and active approaches must meet the various needs related to student activities so that it can integrate with the curriculum (Tanner, 2000). Based on what was discussed about the types of engagement and executive functions, this means considering the conditions for the realization of various engagements in the environment, which is made possible through the functional domains of the mind. Therefore, the relationship between types of engagement and deep learning can be considered as a direct and unmediated relationship, while the relationship between executive functions and deep learning can be considered as a foundational factor in creating different types of engagement, forming an indirect relationship mediated by the types of engagement. Thus, on one hand, the physical environment, with its capabilities, can lead to specific behaviors aligned with deep learning activities and result in various types of engagement. This way of the environment influencing behavior can be referred to as the direct influence of the physical environment. On the other hand, with its ability to affect the functions of various functional domains of the mind, the physical environment can indirectly influence deep learning processes and lead to the emergence of specific behaviors in the environment, thereby improving deep learning. Therefore, the influence of the physical environment on deep learning processes can be discussed from both direct and indirect perspectives (Fig. 4).

The relationship between the spatial components of the physical environment and deep learning will be examined through a systematic review of the literature. This relationship is based on how spatial components influence various types of engagement and domains of mental functioning.

Table 1. Introduction of selected studies based on author name, year of publication, geography, and theoretical foundations of the studies. Source: Authors.

Author name & year of publication	Geography	Theoretical foundations of the studies
Mahat & Emery (2024)	Australia	From the perspective of constructivist learning theory, learning is defined as an active process in which learners are active experiencers who seek to construct coherent and organized knowledge (Mayer, 2004). Therefore, it is believed that effective learning environments should respond to educational reforms and enhance student participation.
Dai et al. (2023)	Taiwan	A smart classroom introduces the use of technology to create an enhanced educational environment. It is characterized by four main features: First, a smart classroom is a technology-rich educational setting that fully integrates both physical and virtual spaces. Second, it provides ICT tools, learning resources, and interactive support for various educational activities, including personalized learning, group learning, Q&A learning, collaborative learning, and mobile learning. Third, a smart classroom can store, collect, compute, and analyze learner data to support optimal educational decision-making. Fourth, it is an open environment that brings learners into a real-world learning context (Li et al., 2015).
Meng & Xu (2023)	China	Healing environments are introduced as spaces that enhance the physical and mental well-being of students on university campuses through physical, psychological, and social strategies (Liang et al., 2023).
Jin & Peng (2022)	China	As a new type of learning space distinct from traditional classrooms, active classrooms are introduced through the lens of constructivist learning theory (Ashworth et al., 2004). These classrooms integrate information-age technologies into the learning environment, resulting in a diverse, flexible, and intelligent learning space (Hacisalihoglu et al., 2018).
Llorens-Gómez et al. (2022)	International	Recognizing that memory and attention are fundamental to cognition and serve as core mechanisms in learning processes (Ritter et al., 2014), this perspective emphasizes the need to examine physical learning environments through the lens of cognitive processes such as attention and memory. It also argues that educational outcomes should be evaluated based on the underlying learning processes.
Kepez & Ust (2022)	Turkey	The concept of Active Learning has been introduced as an approach that encourages students to consciously engage in meaningful learning activities, being aware of what they are doing (Bonwell & Eison, 1991). Additionally, the concept of “affordance” (Gibson, 1979) is used to describe the environmental features that are significant and meaningful for individuals. This theory has recently been adopted as a theoretical foundation for research on active learning environments.
Velusamy (2022)	Malaysia	According to Harrop & Turpin (2013), an ideal informal learning environment meets the behavioral needs of learners—namely interaction, conversation, community, and solitude. Therefore, this study examines the operationalization of informal learning spaces based on learners’ environmental exploration, which is supported by Gibson’s theory of affordance.
Ha & Kim (2021)	United State	Environmental perception is discussed through the lens of cognitive neuroscience: when perceiving the surrounding environment, an individual forms an initial emotional reaction (e.g., liking or disliking), which subsequently leads to cognitive arousal (scene evaluation; e.g., beneficial or harmful), emotional arousal (e.g., positive or negative feelings), and, in turn, physiological arousal (e.g., relaxation), all of which influence behavior (Ulrich, 1983). Therefore, the study highlights the role of the university environment as a factor in reducing mental health risks and enhancing students’ psychological well-being, emphasizing the importance of nature exposure in restoring attention, reducing stress, and improving academic performance.
Wu et al. (2020)	England	The atrium is considered one of the most remarkable spatial innovations in educational environments, developed to support the growing importance of informal learning and social activities. Its role in creating a positive image of the learning environment has been well-established and can contribute to deep learning experiences (Jamieson, 2009). In this study, the atrium is introduced as a supportive space for social interactions that can nurture such experiences.
Holec & Marynowski (2020)	Canada	By addressing the theory of active learning, the emergence of specialized active learning classrooms has been described as a revitalization of educational spaces, and active learning instruction is considered well-suited to active learning classrooms.
Byers et al. (2018)	Australia	It introduces contemporary or innovative learning environments (ILEs) in schools as multi-dimensional learning spaces, inspired by technology and characterized by spatial flexibility, which respond to evolving teaching methods (OECD, 2015). The shift from traditional classrooms to ILEs can create educational settings that prepare students to become lifelong, self-directed learners who are capable of navigating the complexities of today’s technology- and knowledge-based societies (Mulcahy et al., 2015).
Halim & Mustar (2017)	Indonesia	Through the study of environmental psychology and research on the ecology of classrooms related to seating arrangements, designers and planners can understand how classroom environments impact users and how their interactions with others are influenced by the physical environment (McAndrew, 1993). Therefore, the physical design of classrooms should be considered as a subsystem in the process of effective, efficient, and predictable learning, where the scope of the intended activities must be determined before implementing the design (Celce-Murcia & Olshtain, 2000).

Rest of Table 1.

Author Name & Year of Publication	Geography	Theoretical Foundations of the Studies
Arghiani & Shakeri (2021)	Iran	Referring to the idea that the development and growth of new sciences highlight the importance of social-learning environments for learning, an appropriate school environment for children is one where they can develop their social networks with others (Kohlberg, 1971).
Eskandari Torbaghan et al. (2020)	Iran	As Dewey (1926) states, education is a continuous process of experiencing, reconstructing experience, and developing individual capacities that enable a person to control their environment and reach their potential. Given that the progress of education occurs in the physical, social, cultural, and psychological environment, the environment plays an important role in the development of students' personalities and their performance through curriculum, teaching methods, and relationships.
Abbaszadeh Diz et al. (2019)	Iran	Collaborative learning is considered one of the active teaching methods, where students, by being placed in small workgroups, focus on "thinking" rather than just storing information in their minds, and learn skills such as verbal communication, responsibility, sociability, cooperation, and participation. What makes this topic significant is the creation of harmony between the physical environment of the classroom and the educational process to meet students' satisfaction. This is achievable through the creation of spaces related to students' activities—spaces that provide favorable conditions for the physical, mental, emotional, and social development of children, which can certainly be realized by designing space details and paying attention to children's behavioral patterns (Lotfata, 2008).
Abbaszadeh Diz et al. (2020)	Iran	According to Pintrich (2000), students need both cognitive and motivational skills to successfully complete academic tasks and perform well in school. The classroom environment, as an important motivational variable, plays a vital and powerful role in students' academic, psychological, and behavioral performance.

Through the systematic review and extraction of spatial components from the selected studies, two main dimensions were identified: functional and physical. The functional dimension refers to features such as space usage, the relationship between spaces, accessibility, spatial continuity, flexibility, orientation, and other characteristics related to the purpose and mode of space utilization. These features can be categorized into two groups: spatial functions and use and spatial organization (Alexander, 1977; Duffy, 1992). The physical dimension refers to the formal properties of space, including form, shape, geometry, dimensions, proportions, and also physical elements such as furniture, decorations, and materials (Ching, 2014) (Fig. 5).

Accordingly, the spatial components and their influence on deep learning will be discussed in the following section.

• **Spatial components influencing the domains of mental functioning**

In the reviewed studies, certain spatial components influence deep learning through processes related to the domains of mental functioning. Table 2 presents the correspondence between spatial components and the various domains of mental functioning.

The following section presents how the spatial components of each functional and physical dimension

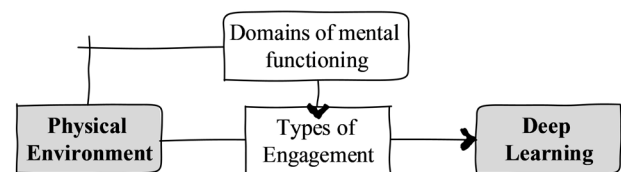


Fig.4. Two ways in which the physical environment influences deep learning. Source: Authors based on Phillips et al., 2010.

influence deep learning through the domains of mental functioning.

- **Spatial components of the functional dimension**

A. Spatial Functions and Uses

In examining the characteristics of spatial functions and uses—particularly through a comparison between traditional classrooms and active learning environments—research indicates improved performance in active classrooms. In these settings, due to stronger spatial support for learning, students' perception of space, furnishings, and decorative elements play a vital role in enhancing spatial awareness. Active learning spaces make spatial perception easier for students, thereby strengthening their understanding of the classroom environment (Jin & Peng, 2022).

Moreover, regarding the effect of personal spaces on memory and attention performance, it is suggested that due to individual differences in learning styles, some students require more personal time to study or reflect on what they have learned. This helps them internalize behaviors or

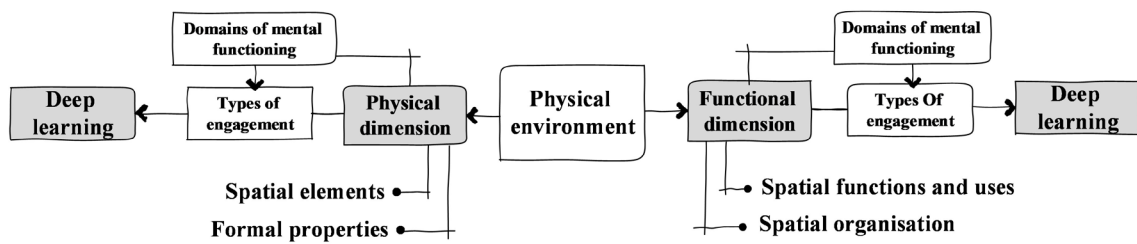


Fig. 5. Spatial domains influencing deep learning based on the two modes of physical environment impact on deep learning. Source: Authors based on Phillips et al., 2010.

Table 2. Cognitive functions and the related spatial components in functional and physical dimensions. Source: Authors.

Author name & year of publication	Spatial components of the functional dimension	Spatial components of the physical dimension	Components of the domains of mental functioning
Jin & Peng (2022)	Active and traditional classes	-	Perception
Eskandari Torbaghan et al. (2020)	Personal space	-	Memory and attention function
Abbaszadeh Diz et al. (2020)	Green space	-	Memory function
Halim & Mustar (2017)	Healing environments: Landscape space, Sports space, Third space, Learning space, Living space	-	Positive emotions
Llorens-Gómez et al. (2022)	Circulation	-	awareness and cognitive processes
Llorens-Gómez et al. (2022)	-	- Form and Geometry, Height and enclosure, Color and texture	Memory and attention function
Ha & Kim (2021)	-	- Biodiversity of plants	Positive emotions

attitudes experienced in social environments and integrate them into their mental processes (Vygotsky, 1978). Such spaces facilitate easier internalization of information—meaning better absorption, retention, and recall—and thus, effectively enhance memory and attention performance (Eskandari Torbaghan et al., 2019).

Moreover, green spaces and the design of outdoor classroom areas in schoolyards can enhance students’ memory performance (Abbaszadeh Diz et al., 2019).

B. Spatial organization: The U-shaped layout encourages greater teacher mobility and eye contact with students, fostering improved interactions between teachers and students, which ultimately enhances attention performance (Halim & Mustar, 2017).

Additionally, circulation paths that support movement and transitions within a space can influence awareness and cognitive processes, ultimately leading to their enhancement (Llorens-Gómez et al., 2022).

- Spatial components of the physical dimension

A. Formal properties of space: Some formal properties of space have also been identified as components influencing domains of mental functioning. For example, the color of the environment plays a role in brain development and facilitates the transition from childhood to adulthood,

thereby enhancing the development of cognitive functions (Eskandari Torbaghan et al., 2019).

Memory and attention functions in learning have been linked to components such as Form and Geometry, Height and enclosure, and color and texture.

The use of cool colors on classroom walls can enhance memory and attention, while high-contrast color combinations may improve spatial memory. Attention can also be strengthened in narrow classrooms with high ceilings and curved geometry, whereas memory may improve in narrow classrooms with low ceilings (Llorens-Gómez et al., 2022).

B. Spatial Elements: In terms of the impact of materials on domains of mental functioning, attention processes have shown better performance in curved interior spaces made of steel, concrete, or glass, whereas memory processes can be enhanced in square or cylindrical spaces constructed with concrete (ibid.). Furthermore, the biodiversity of plants in these green spaces is another factor that can positively influence students’ emotional states through visual and auditory perceptions (Ha & Kim, 2021).

• Spatial components influencing student engagement

In the reviewed studies, processes that influence deep

learning can be identified and distinguished through three aspects of student engagement: behavioral, emotional, and cognitive. Table 3 & 4 present the correspondence between spatial components extracted from the selected studies—specifically those related only to the functional dimension—and components of behavioral and cognitive engagement.

In Table 5, the correspondence between each of the spatial components extracted from the studies—those belonging to both the functional and physical dimensions—and the components of emotional engagement can be observed.

The following section presents how spatial components of both the functional and physical dimensions influence deep learning by enhancing different types of engagement.

- Spatial components of the functional dimension

A. Spatial functions and uses: Regarding various spatial functions, the role of spatial sociability in enhancing social interactions—and thus strengthening behavioral engagement—has been highlighted. Findings indicate that in public spaces, the significance level of behavioral criteria for increasing social interaction ranks higher than that of semantic (symbolic elements in the space), contextual (cultural background), and physical criteria. Moreover, among all sub-indicators, the length of stay and accessibility of public space has shown the highest significance (Arghiani & Shakeri, 2021).

Visual analyses of metric quantitative data, which illustrate

the relationship between curriculum, technology, and space, show that changes in spatial design—particularly through the creation of flexible and technology-rich spaces—lead to changes in teaching elements and student activities. The findings indicate that although teacher-centered instruction remains observable after the intervention of innovative learning environment elements, its duration becomes significantly shorter and more focused on learning objectives. In contrast, active and learner-centered instruction becomes more prominent, where informal learning spaces play a fundamental role (Byers et al., 2018). The role of informal learning environments in fostering behavioral and cognitive engagement has also been studied through components such as social interactions, the active role of the learner, and knowledge construction. These types of engagement have been reported to be enhanced in play spaces, courtyards and campuses, personal and public areas, and learning streets.

Among these, play environments are considered crucial for knowledge construction—natural play spaces being preferred over artificial ones. Personal spaces are also beneficial as they accommodate students’ learning styles, offering more suitable conditions for independent work. Additionally, learning streets, which are public spaces designed for informal learning, can promote interactions, and academic achievement, and facilitate learning processes, idea sharing, and skill development among students (Eskandari Torbaghan et al., 2019).

Table 3. Behavioral engagement and related spatial components of the functional dimension. Source: Authors.

Author name & year of publication	Spatial components of the functional dimension	Components of behavioral engagement
Wu et al. (2020)	Spatial openness of the atrium	Behavioral engagement
Holec & Marynowski (2020)	Active learning classroom	
Byers et al. (2018)	Innovative learning environment: Flexible space, technology-rich spaces	
Halim & Mustar (2017)	U model arrangement	Teacher mobility, Eye contact, lecturer control
Velusamy (2022),	Informal learning environment: open, semi-open, and closed organization	
Mahat & Emery (2024)	Furniture configuration, Spatial configuration	
Halim & Mustar (2017)	U model arrangement	Social Interactions & communications
Kepez & Ust (2022)	Furniture configuration in active classroom	
Wu et al. (2020)	Spatial openness of the atrium	
Eskandari Torbaghan et al. (2020)	Informal learning environment: play space, personal space, public space, courtyard and area, learning street	
Arghiani & Shakeri (2021)	Sociable space	
Kepez & Ust (2022)	Furniture configuration in active classroom	
Abbaszadeh Diz et al. (2020)	Green space, Sociable space, Flexible furniture, Library with individual and group study space	Participation in learning

Table 4. Cognitive engagement and related spatial components of the functional dimension. Source: Authors.

Author name & year of publication	Spatial components of the functional dimension	Components of cognitive engagement
Holec & Marynowski (2020)	Active learning class	Cognitive engagement
Kepez & Ust (2022)	Furniture configuration	Creativity
Mahat & Emery (2024)	Furniture configuration, Spatial configuration	Critical thinking, Searching for meaning, active curiosity
Eskandari Torbaghan et al. (2020)	Informal learning environment: play space, personal space, public space, courtyard and area, learning street	Knowledge construction
Kepez & Ust (2022)	Furniture configuration in active classroom	
Halim & Mustar (2017)	U model arrangement	Motivation

Table 5. Emotional engagement and related spatial components from the functional and physical dimensions. Source: Authors.

Author name & year of publication	Spatial components of the functional dimension	Spatial components of the physical dimension	Components of emotional engagement
Holec & Marynowski (2020)	Active learning classrooms	-	Emotional engagement
Abbaszadeh Diz et al. (2020)	Green space, Sociable space, Flexible furniture, Spatial relationship, Entrances and accesses	-	Sense of satisfaction, Interested presence of students
Meng & Xu (2023)	Healing environment: landscape space, sports space, third space, learning space, and living space	-	Positive emotions: joy, serenity, hope, pride, and interest
Halim & Mustar (2017)	U model arrangement	-	Sense of enjoyment, self-confidence
Dai et al. (2023)	Smart classroom	-	
Velusamy (2022)	Informal learning environment: open, semi-open and closed organization		Preferences
Kepez & Ust (2022)	Furniture configuration in active classroom	-	Willingness
Abbaszadeh Diz et al. (2019)	-	- Color, Form and Geometry, Decoration, Scale, Materials, Landscape	Sense of satisfaction, Interested presence of students

Regarding the function of classroom space as a smart learning environment, the preferences of both teachers and students have been examined. Results indicate that both groups have a positive attitude toward smart classrooms, which reflects an enhancement of emotional engagement in such environments.

According to the findings, students prefer smart learning spaces due to factors such as aesthetically pleasing and comfortable design and the comprehensive integration of diverse functions related to information and communication technologies. In contrast, teachers tend to prefer socially engaging learning environments (Dai et al., 2023).

Moreover, green spaces, socially engaging areas, and libraries that offer opportunities for individual and group study have been identified as spatial functions that positively influence student satisfaction and enthusiastic participation in collaborative learning (Abbaszadeh Diz et al., 2020).

Another topic explored in relation to spatial functions is the concept of healing environments in university settings. Healing environments refer to spaces that promote recovery from unhealthy states or support the restoration of well-being. However, healing is not limited to physical illnesses; it also applies to mental and emotional well-being (Huang & Xu, 2017).

Many current studies on healing environments in university campuses focus on the benefits of natural surroundings. For instance, green spaces on campus can enhance students' restorative perceptions, thereby improving their overall quality of life (Ha & Kim, 2021). In a recent study, diverse spatial functions have been identified as a key factor in creating healing environments. Spatial functions such as landscape space, sports space, third space³, learning space, and living space⁴ have been linked to positive emotions such as joy, serenity, hope, pride, and interest.

Biodiversity, along with a variety of activities, evokes

a range of positive emotional responses and provides a theoretical basis for enhancing the healing quality of the university environment by promoting positive emotions (Meng & Xu, 2023).

B. Spatial organization: Regarding the characteristics of spatial organization, the components of spatial preferences and student social interactions have been examined across three types of spatial layouts—open, semi-open, and enclosed—in informal university learning environments, reflecting both emotional and behavioral engagement.

Studies show that social interaction has the strongest correlation with informal learning environments. Additionally, findings indicate that students' preferred spatial features are better fulfilled when the design of informal learning spaces is integrated with personal context, including individual attitudes, interests, and values.

According to the results, among the three types of spaces, students showed the highest preference for semi-open spaces on campus for engaging in informal learning activities (Velusamy, 2022).

Another issue related to spatial organization in learning environments is the concept of spatial openness. In this regard, the effect of atrium openness on various student behaviors has been examined.

Findings show that spatial openness can influence activities such as individual study, group study, eating, waiting, gathering, and observing the surroundings. Greater openness—meaning a larger visual volume or area—enhances the feeling of “seeing” and “being seen” among students. This increased visual engagement can facilitate activities and, as a result, lead to the enhancement of behavioral engagement among students (Wu et al., 2020).

Greater spatial openness also enables students to visually orient their activities more easily, observe others and surrounding activities, and be seen by friends and peers. Moreover, variations in openness within a space or specific area may influence the frequency of activities among students who require social interactions, such as gatherings and group study.

In addition, a higher diversity of spatial openness allows for flexibility in spatial experience, enabling students to inhabit spaces in different ways based on their moods,

tasks, and experiences. This experience of flexibility through spatial openness suggests that multi-story educational buildings with atriums offer greater spatial diversity, which supports informal learning activities and students' social interactions (ibid.).

In relation to spatial organization, the study of the role of furniture configuration in two types of traditional and active classrooms on students' preferences, types of participation (verbal, etc.), performance, motivation, and creativity, shows the enhancement of various types of emotional, behavioral, and cognitive engagement. According to the findings, students prefer future classrooms to be active learning environments, as they have experienced better learning outcomes in these spaces (Kepez & Ust, 2022). Furthermore, researchers found that increasing the diversity of furniture configurations has a positive and significant impact on learning outcomes (Abbaszadeh Diz et al., 2019).

The enhancement of cognitive, emotional, and behavioral engagement in relation to the configuration of furniture in two types of traditional and active learning environments has been examined through self-assessment of engagement by students. According to the findings, active environments with classroom design and furniture configuration based on active teaching methods yield positive results for both instructors and students. By creating classrooms suited to the instructor's teaching approach, optimal levels of interaction can be achieved (Holec & Marynowski, 2020). Moreover, findings from a survey conducted among male secondary school students indicated that the provision of flexible furniture, coherent spatial connections, and well-designed entrances and access routes plays a critical role in shaping a desirable and effective learning environment. These spatial qualities contribute to enhanced student satisfaction and foster voluntary presence in collaborative learning settings, thereby strengthening different types of student engagement (Abbaszadeh Diz et al., 2020).

Another study examined the impact of spatial organization and furniture configuration on deep learning through components such as critical thinking, meaning-seeking, and students' active curiosity. The findings revealed that designing learning zones with

specific spatial arrangements can influence both teacher performance and student learning, ultimately fostering deep learning. The principles for organizing different types of spaces in this study were derived from Fisher⁵ (2005)'s model of spatial organization, which identifies spatial qualities that support activities such as presenting, applying, creating, communicating, and decision-making. In addition to enhancing cognitive engagement, the conditions in this study were also found to strengthen behavioral and emotional engagement—behavioral engagement through increased student interaction, and emotional engagement by creating learning environments that align with students' personal interests, enabling them to choose learning zones and furniture types accordingly (Mahat & Emery, 2024). Moreover, the U-shaped seating arrangement has been shown to enhance behavioral engagement by encouraging increased teacher mobility, improved eye contact, lecturer control, and more effective communication between teachers and students. This improved interaction contributes to a more enjoyable learning experience for students, fostering greater confidence and motivation during classroom activities (Halim & Mustar, 2017). These outcomes indicate a simultaneous reinforcement of emotional and cognitive engagement.

- Spatial components of the physical dimension

A survey conducted among male secondary school students in Tabriz revealed that formal properties and elements such as color, form and geometry, decoration, scale, materials, and views significantly influence students' satisfaction and interested presence of students. Design features like the use of cheerful colors, intimate and welcoming scales, visual connections to nature, and access to outdoor views from enclosed classrooms enhance emotional engagement (Abbaszadeh Diz et al., 2019). The Fig. 6 illustrates the set of components extracted from previous studies, encompassing spatial elements within both the functional and physical dimensions, as well as deep learning components categorized by types of engagement and domains of mental functioning.

Conclusion

This study, conducted through a systematic review, investigated existing research on the impact of spatial

components of the physical environment on deep learning. To examine how spatial components influence deep learning, theoretical foundations from two areas—physical learning environments and deep learning—were utilized. Based on an exploratory analysis of the literature, it was concluded that spatial components of the physical environment can influence deep learning in both direct and indirect ways. The direct influence occurs through various types of engagement (behavioral, cognitive, and emotional) during the learning process, while the indirect influence is exerted through domains of mental functioning (perception, cognition, emotion, and action).

Based on the proposed models (Figs. 2 & 3), which explain the relationship between behavioral, cognitive, and emotional engagement types, as well as the connection between domains and arenas influencing executive functions, it becomes possible to analyze the processes affecting deep learning. These processes require simultaneous attention to various types of engagement, the relationships among them, and the domains of mental functioning along with their related arenas. However, among the reviewed studies, only a limited number have comprehensively examined the set of factors influencing deep learning in relation to different types of engagement and their interconnections. Most studies have focused on the impact of spatial components on a subset of engagement elements or mental functioning domains. Moreover, among the interactions between the intrapersonal, interpersonal, and symbolic system arenas with the physical arena, greater attention has been given to the intrapersonal and interpersonal arenas in relation to the physical environment, while the connection between symbolic systems and the physical environment has received less consideration.

By extracting the spatial components that influence different types of engagement and domains of mental functioning, these components were categorized into two main dimensions: functional and physical. Functional components were classified into two categories: (1) spatial functions and uses, and (2) spatial organization. Physical components were also grouped into two categories: (1) physical elements, and (2) formal properties of space (Figs 7, 8, 9 & 10). As observed in the reviewed studies, spatial components related to the functional

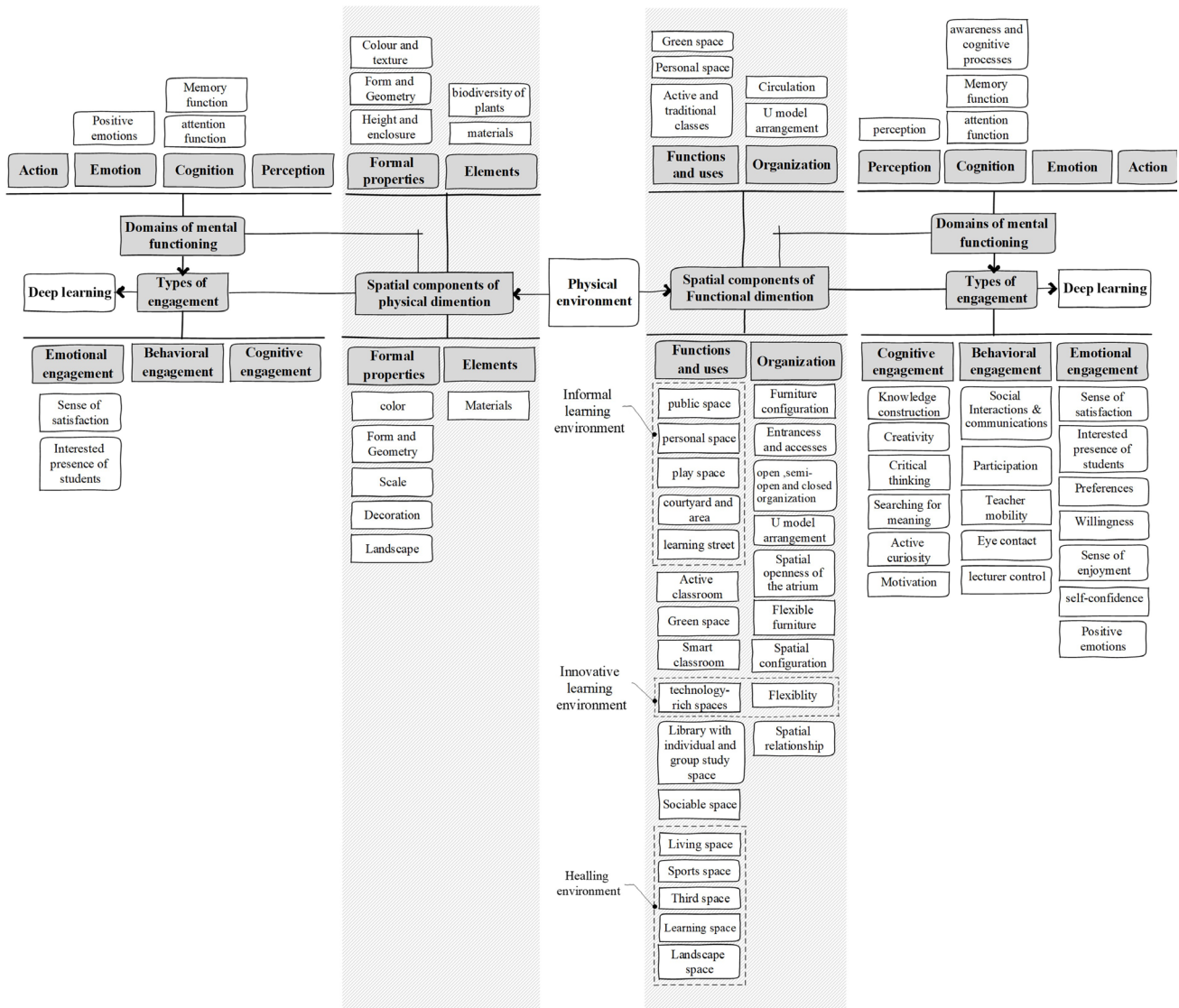


Fig.6. Components extracted from the literature, including spatial components across two dimensions—functional and physical—and deep learning components categorized into types of engagement and domains of mental functioning. Source: Authors based on Phillips et al., 2010.

dimension have been considered more significant than those of the physical dimension.

The functional dimension, which reflects the purpose and mode of spatial use, plays a more prominent role in learning processes and is of greater importance as a facilitator of learning. Accordingly, its impact on deep learning has been primarily addressed through direct relationships with different types of engagement, while its connection to domains of mental functioning has received less attention. Conversely, spatial components associated with the physical dimension have been less analyzed in relation to types of engagement, yet they have shown a more substantial role in relation to mental functioning domains.

Therefore, future studies need to pay more attention to

the domains of mental functioning, given their influence on the formation of different types of engagement in learning activities. Moreover, the physical aspects of space, alongside functional ones, should be considered more equally in spatial analysis.

Declaration of No Conflict of Interest

The authors declare that they have no conflict of interest in conducting this research.

Endnotes

1. Scopus, Science Direct, Web of Science, Google Scholar, Springer.
2. Elmnet, SID.
3. The concept of the Third Space is based on the idea of the Third Place, which primarily refers to spaces where students can strengthen social connections and

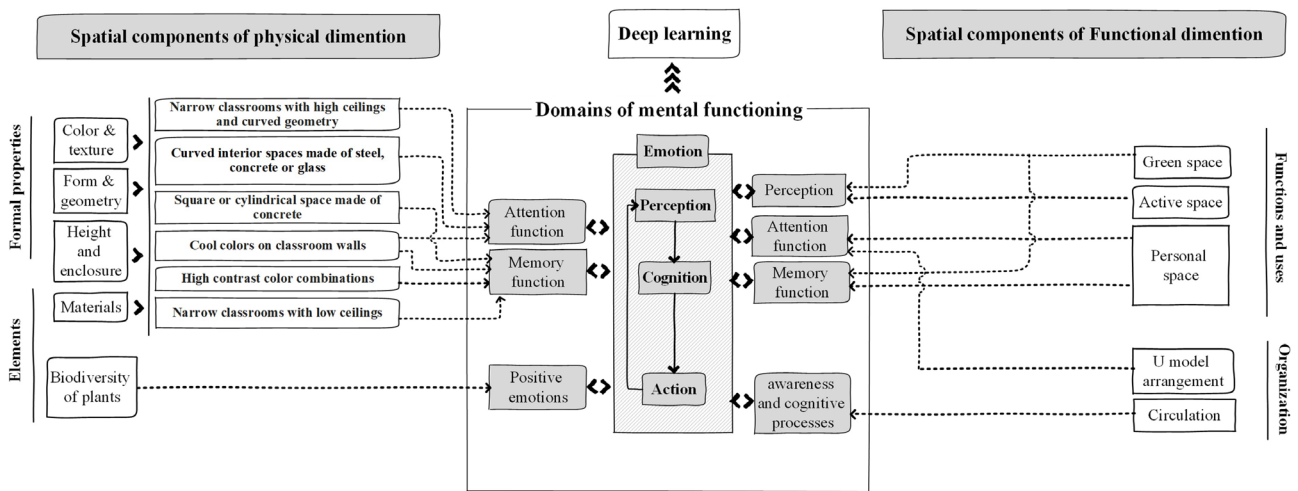


Fig. 7. The impact of physical environment components on deep learning through domains of mental functioning. Source: Authors based on McCloskey et al. 2009; Phillips et al. 2010.

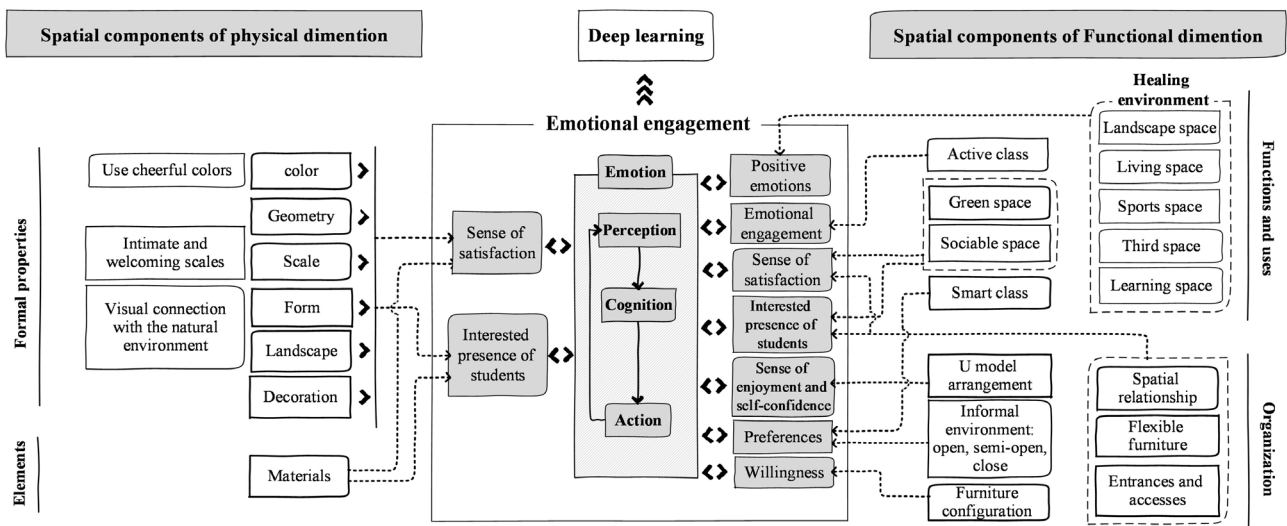


Fig. 8. The impact of physical environment components on deep learning through emotional engagement. Source: Authors based on McCloskey et al. 2009; Phillips et al. 2010.

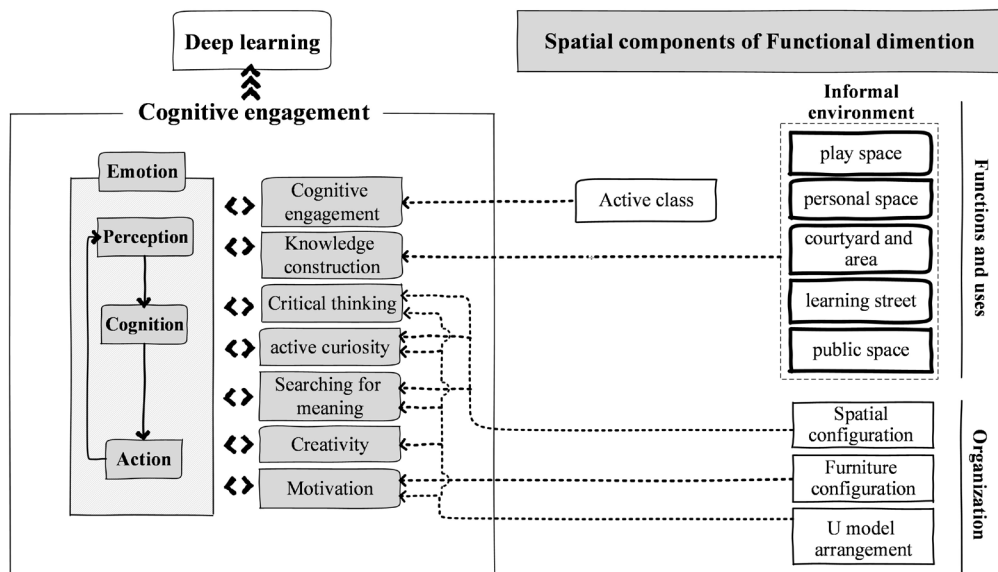


Fig. 9. The impact of physical environment components on deep learning through cognitive engagement. Source: Authors based on McCloskey et al. 2009; Phillips et al. 2010.

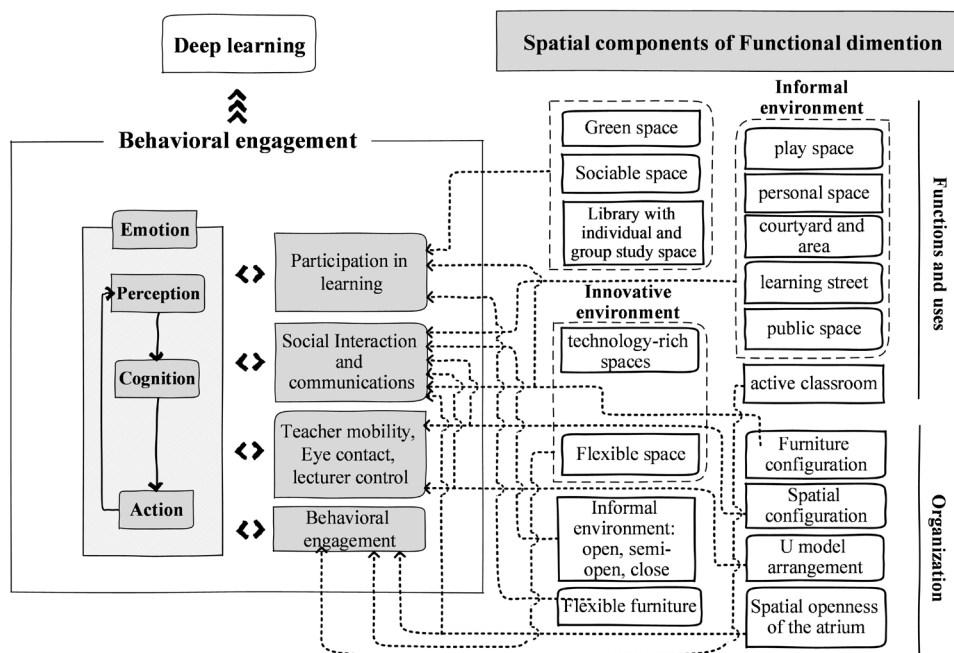


Fig. 10. The impact of physical environment components on deep learning through behavior engagement. Source: Authors based on McCloskey et al. 2009; Phillips et al. 2010.

engage in informal social activities, such as coffee bars, retail pavilions, and food plazas.

4. Living Space refers to places where students reside and rest, primarily including dormitories.

5. Keen Fisher (2005): The three learning zones established in the classroom include the “Sharing” zone, where the teacher collectively delivers information to students—similar to Fisher’s instructional activity of presenting; the “Creating” zone, where students actively engage in learning and work individually or collaboratively on a topic; and the “Feedback” zone, where students provide feedback to their teacher either individually or in small groups.

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