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Design Guidelines of Convergent Education Environment Based on Design Thinking through STEAM Theory

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Abstract

I proposed the architectural guideline for educational environment based on design thinking approach to integrate and enhance learners' activities and achievements. The physical environment of design education learning space should be applied by teaching methods and learning activities, especially for STEAM-based convergent education, the architectural space conditions should support the design process based on design thinking. The learning environment conditions influence design education with physical design factors and learners' communication, and the flexible environment based on design thinking, which is crucial for design education. The 3 steps of design thinking experiences also allow students to learn the context of ideas, skills and outcomes. Therefore, I argued that the learning surrounding based on design thinking needs flexible and mobile, connected, integrated, organized, and team-focused environments to support learners' understanding, participation, and collaboration, and to achieve the design process based on research findings. For spaces for convergent learning environments based on design thinking, common design principles should be reviewed, such as coexistence with technology, safety and security, transparency and spatial extension, multi-purpose space and outdoor learning.

Keywords: *Architectural Guideline, Design Thinking, Design Process, STEAM*

1. Introduction

1.1 Research Background and Purpose

The pace of social and technological change is disorienting, and modern learning environments are evolving to keep pace. Part of making educational spaces work, according to architects, is incorporating long-term flexibility. The convergent education based on STEAM (Science, Technology, Engineering, Arts and Mathematics) theory is an integrated project-based learning program, students need small-group areas to plan and discuss their projects. Based on this study, I intend to present design guidelines for the learning environment, focusing on the design thinking process and the convergence education curriculum. The design environment elements constituting the physical learning environment are important factors that influence the learner's expected behavior and support the learner's behavior. This study suggests the direction of a convergent learning environment for the design process centering on design thinking theory.

1.2 Scope of Study

The range of this study is to identify the interrelationship between design thinking and visual perception education, and the convergent learning environment, and to examine the connection between design principles and the learning surroundings with a focus on design elements. First, based on the STEAM education model,

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analyzing the design thinking concept and the visual perception education, second, the physical and architectural characteristics of the learning environment affecting the learners' activities are examined, and third, the directions of the design learning environment are suggested. In this study, I classify the convergent education model and the stages of the design principles to suggest design principles for the learning environment based on the understanding of design thinking to support and induce various learning activities for mutual interaction.

1.3 Research Method

As for the methodology for this study, theoretical background review for academic analysis and review of previous studies were performed. First, the concept of the STEAM and design thinking approach was grasped in terms of convergent education through previous studies. Second, the characteristics of the design thinking process and the theory and correlation of visual perception education were analyzed through literature review and previous studies, and the relationship between the convergence characteristics of design education and the physical condition of the learning environment was examined. Third, the conditions of the learning environment were classified in terms of the effectiveness of education according to the learning stage, learning form, and learning behavior, and the design conditions of the learning environment were examined from the educational point of view. Fourth, the design principles and design elements of the learning environment were presented from the perspective of convergence education.

2. Theoretical Experiments

2.1 The Integrated Value of Design Education

Design education has the purpose of inducing integrated experiences and creative thinking through visual thinking and a given problem-solving process. In order to induce active participation of learne rs for an integrated approach, it is necessary to develop convergent educational contents that combin e related fields [1]. It has been discussed that design education requires basic education in humaniti es, arts, science, and technical engineering, and the integrated nature of design is an important chara cteristic of design. The integrated experience using a design integrates various academic fields throu gh interdisciplinary exchanges and enables a structure that is very suitable for convergence talent ed ucation. The integrative value of design is the comprehensiveness of academic fields, and design ed ucation should be generalized because it enables professional education in terms of problem solving, conceptualization of thinking, visualization of ideas and communication [2]. The intrinsic value of d esign education can be defined as the ability to solve problems, to think structurally and non-verball y, which means that design has the potential to be integrated into liberal arts education [3]. First, d esign implies the legitimacy of education to learn problem-solving ability to solve real problems. Se cond, it learns the recognition of the inherent style of objects, the structural integration, and the stru ctural way of thinking that synthesizes them. Third, the design uses images to communicate in a no n-verbal manner such as sketches in the process of embodying inner thinking. As a result of researc h on design education for children emphasized that a convergent approach is necessary [4]. The res earch results show that children use art to express creative ideas and exchange opinions, educate tec hnology to develop ideas, and have a holistic understanding of science to evaluate the possibility of outcomes and utilization was required. In other words, design education can cultivate creative thinki ng ability through a data research stage for problem-solving, a process of visualizing ideas, and a c onvergent curriculum for presentation and analysis for exchange and communication. Figure 1 shows a detailed presentation of the integrated effect of design education, based on the results of the desig n early education training and workshop implementation of the Korea Institute of Design Promotion and the design life lecture trial operation result report [5].

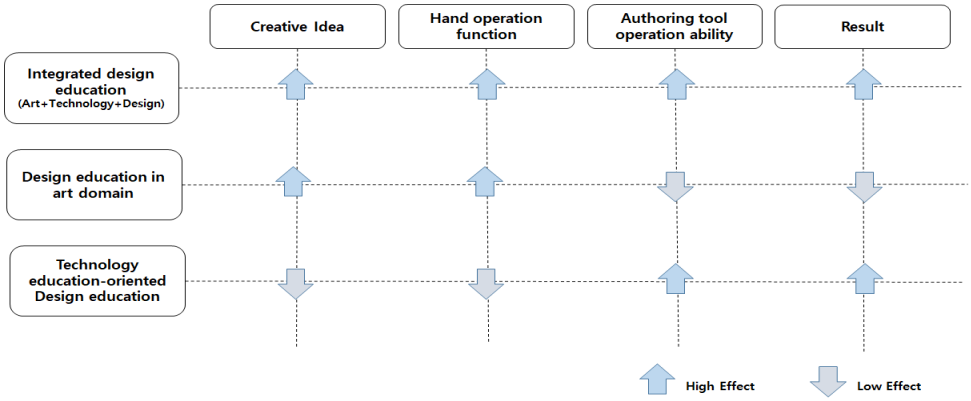

Figure 1. The integrated effect of design education

2.2 Design Thinking and Visual Perception Education

The concept of design thinking started from 'Design as a Way of thinking' in 'The Sciences of the Artificial' [6]. In 1991, David M. Kelley, founder of the global design firm IDEO, and Tim Brown, CEO of IDEO, described design thinking as a way of thinking that applied the designer's sensibility and working style and defined the designer's sensitivity and working method to satisfy the desire for business strategy. They present a methodology using approaches as a service thinking process methodology which are Inspiration-Observation and inspiration, Ideation- Idea acquisition, Implementation-Beta service, and Prototype. It is described as the step of obtaining the best answer by repeating the steps of failure and improvement by making and experimenting [7]. The characteristics of design thinking are as follows. First, design thinking can be defined as a way of thinking. To solve a given problem, the designer finds alternatives through divergent thinking and repeats the process of transforming the selected alternative into reality through convergent thinking. The diffusional thinking process understands consumers and seeks multifaceted alternatives through the repetition of convergent thinking that finds an optimal solution to a given situation. This process is integrated thinking of intuitive thinking that goes beyond the logical connection with the analytical thinking about the problem. Second, design thinking can be said to be a methodology, and design thinking education can be extended to creativity education with the 3 core activities: inspiration, ideation, and implementation [8]. Figure 2 illustrates how the Core Activities relate to each other. The inspiration step is the inducing actions such as observation and exploration as a step for inspiration, the ideation step is finding ways to solve problems and developing specific ideas and the implementation step is to obtain the most suitable answer through repetition of improvement and failure processes to produce a prototype for solving a problem. This process uses visual thinking to solve problems from various angles through imaginary interaction. In addition, while imagining the possibility of other solutions, the process of continuing the analogy of images proceeds. In Art and Visual Perception, Rudolf Arnheim (1904~2007) mentioned the importance of the relationship between visual perception and the brain. He noted that human beings perceive form as a general structural characteristic, and on the definition of vision, understand form as an overall visual structure [9]. He stresses the importance of visual perception because every perception is linked to thought processes, every cognition is intuitive, and every observation is linked to the invention. Design education involves mental manipulation activities that store information through visual information and thinking. A person capable of visual thinking interprets a problem from various perspectives due to the active interaction of images [10].

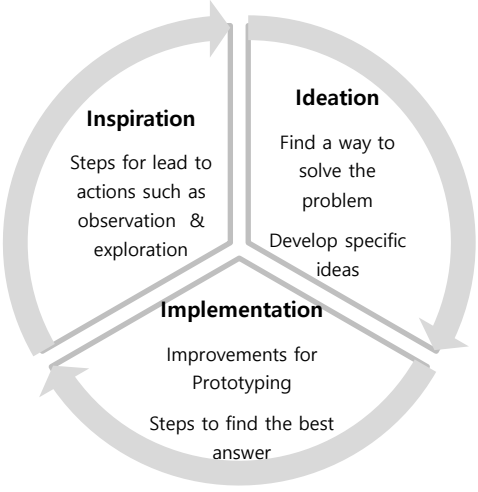

Figure 2. The core activities of design thinking

2.3 Design Principles for STEAM based Convergent Learning

The STEAM-based convergent education is to inspire students to inquire, think, investigate, and innovate in teams and the goals are generating multiple ideas, communications, innovative thinking, problem-solving, productive teamwork, and decision-making for start build-up. STEAM can be taught in only one classroom or one subject, such as math or science, or it can be taught tightly integrated, with teachers of various subjects planning together. It can be integrated throughout the whole school, or as an elective or after-school program and is affecting the classroom, school design, and renovated environment. The best architecture and designs for convergent learning classrooms are adaptable, flexible, mobile, and ergonomics [11]. classrooms to constant connectedness, instructors can better engage students and advance learning outcomes. Centered on project-based learning, an efficient STEAM classroom fosters a positive experience that allows learners to collaborate, analyze, create, solve problems, and build ideas with themselves. Figure 3 displays the goals of STEAM education and Figure 4 indicates the educational effect between learning methods and reflection of learners' activities.

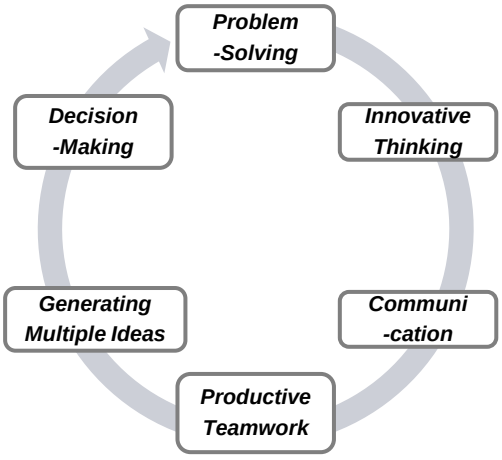

Figure 3. The goals of STEAM education

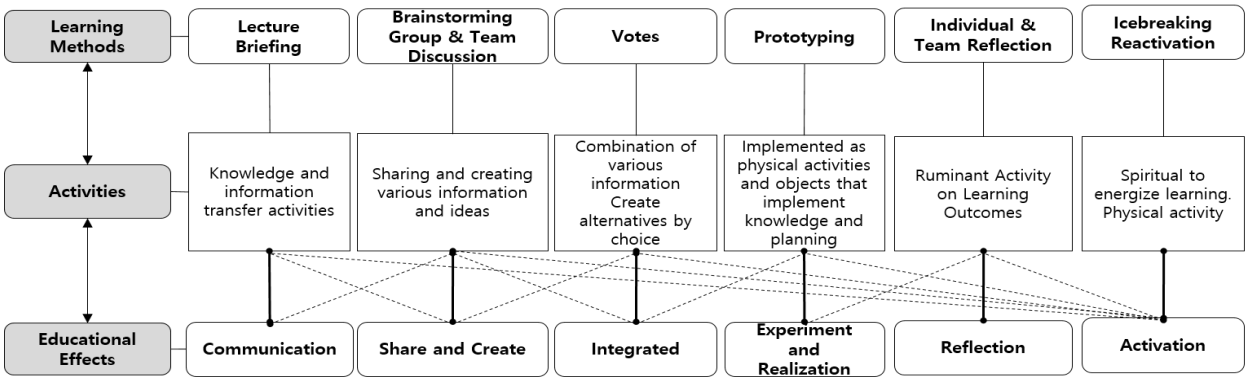

Figure 4. The learning methods and learners' activities

3. Results

3.1 The Architectural Requirements for Learning Environments

According to the architects, the working part of the educational space is to incorporate long-term flexibility, and the five common design principles for the learning environment proposed by the architects are technology integration, transparency and safety, multi-purpose space, and outdoor learning [12].

3.1.1 Technology Integration

Technology integration can embrace and prepare students for the types of work environments and companies they are going to be working for when they get out of school. Recently, school technology represents ubiquitous, invisible, personal, and mobile so, wiring the entire school-including the outdoors-is necessary. For that, projectors, screens, and sound systems are migrating out of classrooms and into hallways, common spaces, cafeterias, and even stairwells. Students can access the network anywhere on campus, and view and share work on digital displays throughout the building. The effects can reduce students' dependence on the teacher, promoting peer-to-peer collaboration, and widening the sphere of learning from the confines of the classroom to the whole school grounds. Also, it is necessary to integrate Wi-Fi and tech throughout a school, and a need for spaces with high-tech tools like 3D printers.

3.1.2 Transparency and Safety

In the US, architectural transparency, the principle of visual interconnectedness, is an emerging standard in a new school. Visual interconnectivity in architecture is important and safer to have because students can get teachers' protection by connecting with students around the school. According to educational architects, opening a line of sight into adjoining areas makes learning communal, inspires collaboration, and generates a public forum for sharing and observing student work. Through visual transparency, students can create visual communication about teaching and learning. Learning impact is promoting a sense of collaboration and enabling students to gain inspiration from the work of others. The construction of internal spaces such as classrooms, corridors, and cafeterias has to give way to open layouts that accentuate transparent partitions and continuous lines of view, for innovative education environments. Also, open, and transparent design emphasizing windows and clear lines of sight, even between floors, reduces bullying opportunities and improves the learning environment for vulnerable students.

3.1.3 Multipurpose Space

For the flexibility of the school structure, the space diversity to contribute to learning should be expanded. According to architects, part of making educational spaces work is incorporating long-term flexibility so that technology, curricula, and pedagogies, can support those changes. Corridors are being widened to become extensions of the classroom, stairs are turning into seating space, and walls throughout the building are doubling as writing surfaces or displaying Wi-Fi-enabled TV screens. Single-use spaces could be designed to function as multi-function spaces such as hybrid theaters and media centers. The flexible spaces should also meet the everyday needs of educators to create instructional variety such as direct instruction, independent performance, and group work by altering their environments. Lightweight chairs, beanbags, area rugs, tables of different heights, and movable or foldable walls can transform alcoves into quiet reading spaces, which can in turn be modified to suit project-based learning or direct instruction.

3.1.4 Outdoor Learning

A 1998 study concluded that when learning is hands-on and made relevant to students' surrounding environment, they are more engaged in the curriculum and perform better on academic tests [13]. Also, research reported that there are many benefits from learning in the outdoors, including improved creativity and reduced stress [14]. According to leading education architects, some outdoor learning environments are simply spaces that facilitate learning like a group of benches, an amphitheater, or a partially covered workspace with amenities like Wi-Fi and supplies. These outdoor spaces are designated for instruction, presentations, or independent and group work, but they provide a creative perspective for students who spend most of the school days indoors.

3.2 Design Principles for Convergent Learning Environments

The design elements of the learning environment are categorized into pedagogy, space, and technology. The design of an ideal learning environment requires a pedagogical approach that can reconcile learning objectives, learning concepts, and spaces of action. According to the educational purpose and content of the teaching, the teaching method is evolving into lectures, group activities, task solving, and simulations. Type discussion-type sharing and creative activities, integration activities for synthesizing opinions and alternatives, experimentation and realization activities for reflection of acquired knowledge, and prototyping are included. The physical learning space consists of items of spaces, places, and properties, and the technology is reflected in the items of the media lab, smart classroom, and experimental teaching method. Table 1 shows the opinions of experts who presented classroom design principles for STEAM education focusing on flexibility, mobility, connectivity, integration, organization, flip learning, and team focus were analyzed and presented. Implementing six principles outcome of an effective classroom design that creates a positive circumstance where learners can collaborate, learn, and innovate [15]. Convergent education requires flexibility in the learning space because the form of education is determined by the collaborative project related to practice rather than unilateral knowledge transfer [16]. Structural flexibility can be secured by providing the independence of individual spaces for convergence education and the provision of an adaptive space that can integrate individual spaces and an intermediate area that connects individual spaces [17]. So the conditions of physical spaces should provide informal space, constant connectivity, adaptable classroom, project-based learning, active learning, and customized teamwork space.

Table 1. STEAM classroom design principles

Principles	*Contents*	*Elements*
Flexibility & Mobility	Execution of diverse teaching and learning methods Expanding the application of teaching and learning resources	Open space | Adjustable space | Lightweight and movable furniture | Mobile supplies
Connection	Connectivity with various learning resources Link with nearby classrooms, local and onsite	Spatial Connection | Digital Technology | Network Connection
Integrated	Safety for cultural, psychological, physical, and medical surroundings	User convenience | High accessibility
Organized	Effective & productive environment for materials & time	Storage | Containers | Shelving
Flipped Learning	The role of the teacher is the guidance, explaining the problem-solving process, facilitating discussion & answering questions	Flipped classroom | Learn through hands-on activities & working in team groups
Team Focused	Learn through working in teams & hands-on activities Improve and assist learner participation and collaboration	Grouping activities | Shared space for learning outcomes | Sharing the learning process

3.3 Design Guidelines and Features for Convergent Learning Environments

The convergent learning is an integrated project-based learning program, so students need small-group areas to plan and discuss their projects, so the learning environment should be adaptable, flexible, mobile, and ergonomic. The lab and classroom should be used as a combination space where students can move from discussion to hands-on work and back during a single class period. Technically that means science, lab, classrooms with a minimum of 5.57m^2 per student, and a maximum of 24 students. In terms of engineering labs and classrooms for STEAM education, classrooms for CAD practice should be added. Another important feature is student project spaces that are readily accessible from the science classrooms, as well as access to the outdoors. That access is essential for students to test creations and display them, without the limitations of walls and ceilings [18]. Table 2 represents the design features for designing technology, furnishing, seating, desk and table, and storage in a convergent learning classroom.

Table 2. Design features for convergent learning classroom

Contents	*Guidelines*	*Design Feature*
Adding Technology	The ability to instantly connect with global data and other resources Connectively is essential for 'bring-your-own-device (BYOD)'	Tablet-type devices traveling with students and connect to a wireless network Supply the power for students' computers, tablet devices, and Wi-Fi The engineering aspect of the program including CAD with screens, printers including 3D, and plotters
STEAM-Friendly Furnishings	Creating a learning environment according to the learning type with modular furniture Form a variety of space layouts using modular furniture	The furniture should be modular and sturdy for functionality and maximum longevity.
Seating	Classroom seating must offer a range of movements, positions, and functions.	The convergent learning classroom should support the students' behaviors such as standing, sitting on stools, rolling on chairs, and casual lounging to collaborate.
Desks and Tables	Project-based learning requires desks or tables capable of being arranged into compact pods that fit six to eight students. Having the flexibility and ability to rearrange the desk for use in multiple ways is important.	Table design and materials must be expanded to accommodate the STEAM. Work surfaces should stand up to chemicals, heat, and height varies Large work area and stability

Storage	Most of the student projects within the STEAM environment will take place over more than one class period, so it is essential to have space to safely leave or store in-progress projects.	Mobile storage for educators to organize hands-on project materials and tools Mobile units to house projectors and computers for presentations

4. Discussion

The convergent activity based on design thinking successfully integrated multiple subjects in a natural way, integrating these important concepts into the curriculum and learning environment to help learners become creative circumstances. The design principles of the spatial model developed to support convergent learning activities, learning by doing, and logical thinking support learners' activities in team-based laboratory activities of discovery-based learning and problem-based learning. The flexibility of the learning space is essential for teaching in the form of a collaborative, practice-based project. A design plan is needed to ensure flexibility, mobility, and connectivity of spaces to support learner activities. Modular furniture, furnishings, and storage can be used to increase the flexibility of a space, allowing learners to easily collaborate with team members with different backgrounds and knowledge. As a result, learners experience a space where they have frequent and active contact and interaction, which helps to increase their understanding of other disciplines. Figure 5 shows the design guidelines and a design strategy that are needed to control the ability of visual communication and physical association of learners by using the proportion of structural features, material, and form of the space. It provides a learning environment that maintains visual integration of space and uniqueness of area through open, spatial zoning using corridors, walls, floor, stairs, architectural transparency, ceiling height, and indoor/outdoor courtyard.

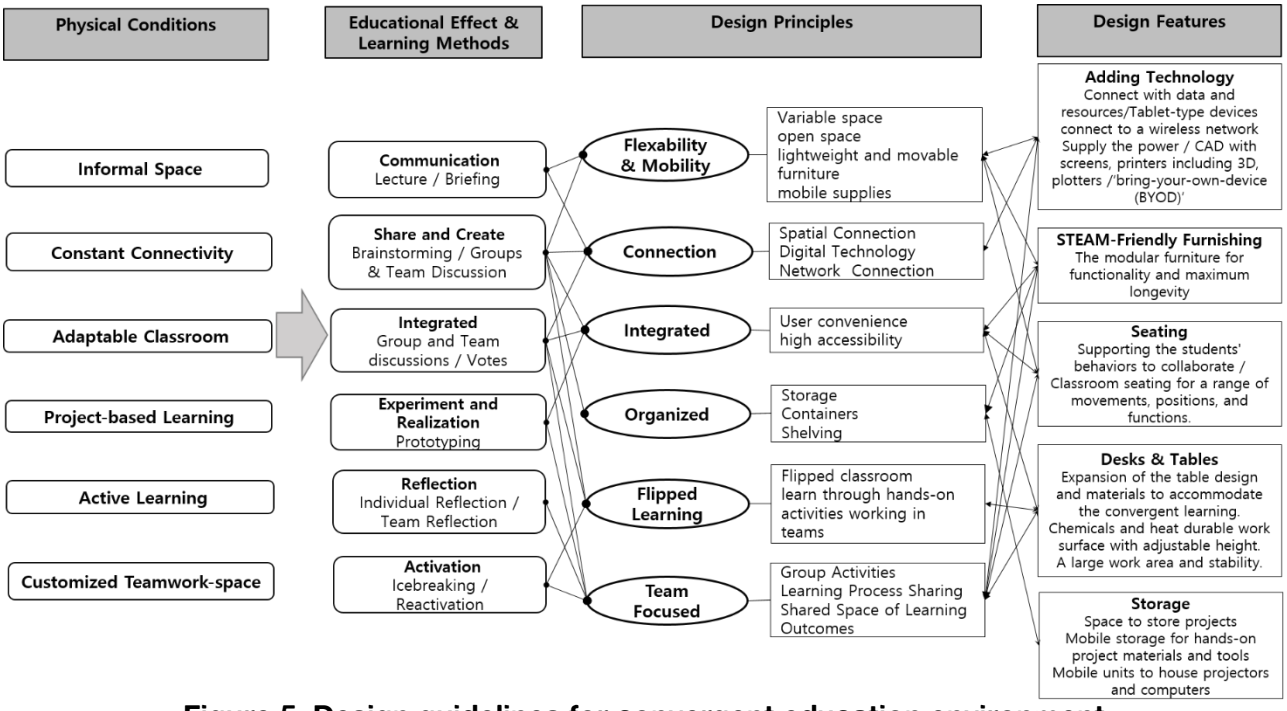

Figure 5. Design guidelines for convergent education environment

5. Conclusion

Learning environments based on convergence education require informal spaces for project-based learning, adaptive classrooms for active learning, and continuous connectivity for teamwork interspaces. The flexibility, mobility, and connectivity of the learning environment allow learners to work on projects that require access to digital tools or software, group meetings to discuss resources, and areas where they can plan, discuss and solve problems. Collaboration and hands-on learning are essential elements of convergent curriculum planning,

so learning environments should provide flexible and collaborative spaces for group projects or individual learning where hands-on experience plays an important role. Informal spaces such as open lounges, private study spaces, outdoor areas, and coffee shops provide students with a variety of environments and experiences for flexible collaboration. Corridors should be adaptable as classroom extensions, staircases could be transformed into seating areas, and the walls of the whole building should function as hybrid spaces depending on the type of learning. Mobility can be created by nesting spatial elements and taking advantage of flexible modular unit furniture and partitions. This means that learners can move directly from class lectures and discussions to design projects without having to travel. The ability for learners to engage in small group activities and interact with each other is the benefit of active learning spaces. These areas need to be equipped with modular tables with removable seating, and individual spaces in each area should ensure easy access between the learning process and the learner, and modular variability and mobility for secure contact between the learning process and the learner. Broad and accessible technology for continuous connectivity is an essential aspect. There should also be a variety of digital technologies and software programs, such as virtual reality, that allow learners to explore the world around them.

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