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Design Principles for Learning Environment based on STEAM Education

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Abstract

In this study, a learning environment based on STEAM theory was proposed to support and improve learners' activities and achievements for convergent design education. The learning environment design influence STEAM education with intentional design and schedule coordination, schools can create informal environments that are crucial to STEAM education. The physical surroundings of the learning space should be applied to teaching methods and learning activity, especially for STEAM-based education, physical space conditions should support the learner's design thinking and process. Furthermore, STEAM-based education environment should support a vast array of experiences that allow students to learn the context around ideas and skills. For spaces for learning environment based on STEAM, common design principles should be considered such as technology integration, safety and security, transparency, multipurpose space, and outdoor learning. Therefore, the learning environment based on STEAM needs flexible and mobile, connected, integrated, organized, flipped, and team-focused surroundings to support the learners understand, participate, cooperate, and accomplish the design process.

Keywords: *Learning Environment, STEAM Education, Design Process, Classroom*

1. INTRODUCTION

The modern learning environment is evolving to keep pace with social and technological change. STEAM is an integrated project-based learning program, where students need a flexible physical area to plan and discuss projects. The purpose of this study is to propose a physical element and learning environment for convergence design education that influences predictable learner's behavior and supports the learning process based on the STEAM concept and design thinking and process. In other words, this study suggests the direction of the convergence learning environment for the design process centered on STEAM education.

1.1 Scope of the Study

This study defines the concept of STEAM education and the learning environment, and sets the research scope to investigate the relationship between design principles and the learning environment and design characteristics. Based on the gradual approach to the STEAM education model, this study aims to present the direction of the learning environment for convergence design education and analysis of the physical characteristics of the learning environment that affect the learner's activities. Based on the understanding of convergence design education, design process, and convergence education, and classification of characteristics and physical conditions of STEAM education, design principles for a learning environment that can support various learning activities were presented.

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1.2 Research Method

An academic review was performed on the theoretical background and analysis methods of previous studies. First, prior research related to design education and literature analysis were performed, and the theoretical background of the design process was considered. The relationship between design principles and learning environment on the characteristics of convergence design education and learning environment was investigated and analyzed. Second, the concept of STEAM education in terms of convergence education was identified, the concepts and principles of the learning environment were analyzed from an educational point of view, and the physical conditions of the learning environment and the characteristics of STEAM were classified according to the learning stage. Third, through a case study in the United States Design principles and directions of design learning environment were investigated focusing on design features.

2. THEORETICAL BACKGROUND OF STEAM EDUCATION

2.1 Concept of STEAM Approach

The creative process associated with design is uniquely applied to STEAM-based models from an educational point of view [1]. The STEAM concept encourages students to develop solutions that integrate different disciplines and extends across content domains [2]. The STEAM education model is based on a creative paradigm, and STEAM education is essentially an active learning of PBL (Problem-Based Learning). PBL covers a wide range of topics, disciplines, and connections between behavioral learning and simulation, with an emphasis on hands-on and controlled experiences. This STEAM education represents the integration and symbiotic relationship between the disciplines of science, technology, engineering, art and mathematics, and in each area of contribution, immerse students in a diverse knowledge base to improve various outcomes. The foundation of STEAM education is engineering and design, and K-12 education in the United States focuses on engineering design and developmentally appropriate knowledge and skills in mathematics, science, arts, and technology [3]. Table 1 shows the engineering “habits of mind” adopted from STEAM education, with key concepts in systems thinking, creativity, optimism, collaboration, communication, and ethical considerations that can be incorporated into classroom environments and educational activities [4]. Engineering design utilizes political influences, budget constraints, timelines and available resources to contribute to solution development and problem solving. A team of engineers from different disciplines in engineering will work around the congestion and use this technology to design multiple mock-up traffic solutions to test before full-scale implementation.

Table 1. The Engineering Habits of Mind

Concept	Contents
Systems thinking	Have students use graphic organizers to visually represent concepts Discuss relationships between and among variables in day-to-day real-life situations
Creativity	Provide assignments that require imagination Have students develop multiple solutions to problems in their own lives
Optimism	Encourage students to develop workable solutions to problems large and small Provide students with examples of how cultures and societies have overcome situations through science and engineering
Collaboration	Use cooperative groups, collaborative whole-class or team projects, and co-teaching Challenge-based learning provide students with engaging, collaborative experiences for understanding and solving real-world local and global problems
Communication	Provide students with understanding through explicit instruction and an opportunity to practice communication skills in face-to-face, also real-world online environments
Ethics	Encourage, model, and require ethical thinking and rationalization in teams to design solutions and solve problems. Model desired behavior using strategies such as think-aloud

2.2 Design Process Methodology

The basic structure of the design process is problem understanding, problem solving, and evaluation process, which enables effective problem solving through conceptual thinking and cognitive development processes [5] [6]. Nigel Cross emphasized the educational value of general design that can be integrated with other disciplines, and he defined the essential value of design education as practical problem-solving ability, structural thinking, and non-verbal thinking [7]. In design education, the learner's conceptual thinking and cognitive development experience are formed through the development of practical activities according to the subject and content of learning. The development of conceptual thinking is formed in the process of actual planning, testing, discussion and production of learners according to the learning content and purpose, and cognitive development comes from the learner's experience of using tools and materials for visual representation of objects and spatial understanding. The design process that forms a cyclical structure is applied to integrated thinking, creative idea proposal, and visual thinking process for problem understanding and solving stages, and Table 2 classifies the design process and stage characteristics, learning processes and types.

Table 2. The Circularity of The Design Process

Concept	Step	Activity
Understand the problem	Implementing for the next step by setting design ideas and direction	Identify and understand design issues / Provide rational evaluation guidelines and standards for design solutions
Solve the problem	Propose design solutions in comprehensive steps	Design drafting process based on the designer's imagination / Implementing various creative techniques through problem understanding, analysis and placement
Evaluate the performance	Evaluation and reflection stage for design solutions	Evaluate the optimal solution derived based on the problem solving method presented in the problem understanding stage

2.3 Design Principles for STEAM Education Environment

A study by Lieberman & Hoody concluded that students participated more actively in the curriculum and performed better on academic examinations when they were hands-on forms of learning related to their surroundings [8]. Teaching methods that include lecture formats, group activities, task-solving processes and simulations are very important in pedagogy, and teaching methods are evolving in various ways depending on the educational purpose and content. The design elements of the learning environment can be classified from an educational, spatial, and technical point of view, and in Figure 1, the details of the spatial design elements are classified into spaces, places, properties, and components. Lecture-type delivery activities, discussion-type sharing activities and creative activities, activities for integrating opinions and alternatives, experiments and realization activities for prototyping, and reflection of acquired knowledge can be classified into types of learning methods from an educational point of view, Table 3 shows It shows the relationship between learning methods and reflective activities on learners' activities for STEAM goals. STEAM classrooms should be inspiring learning spaces, and Table 4 shows the design principles of flexibility, mobility, connection, integration, organization, flipped learning, and a team-centric approach based on the results analysis of expert opinion on STEAM education. Implementing these six principles result in an effective STEAM classroom design that creates a positive environment where students can learn, innovate, and collaborate [9].

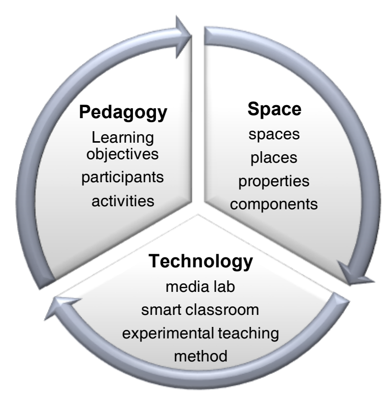


Figure 1. Design Factors for Learning Environment

Table 3. Learning Methods, Activities, and STEAM Goals

Types	Learning Method	Learning Activities	Goals of STEAM
Communication	Lecture & briefing	Knowledge acquisition and information transfer	• Problem-Solving
Share and create	Brainstorming & Team discussion	Sharing various information and developing creative ideas	• Innovative Thinking
Integrated	Team discussion & Decision-making Process(voting)	Presenting alternatives through the combination and selection of various information	•Communications
Experiment and realization	Prototyping	The process of realizing an object through physical activity to realize knowledge and plans	• Productive Teamwork
Reflection	Individual & team reflection	Reflective activities on learning outcomes	• Generating Multiple Ideas
Activation	Icebreaking & reactivation	Mental and physical activities that energize learning	• Decision-Making

Table 4. Effective Design Principles for STEAM Classroom

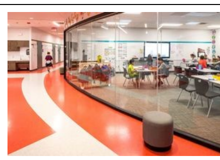
Principle	Content	Design Element	Space Condition
Flexibility & Mobility	Various implementations of teaching and learning methods Use of a variety of teaching and learning resources	Open space, variable space, lightweight appliances, movable furniture, mobile supplies	• Informal Space
Connection	Linking various learning materials Connections with local and field sites and classroom exchanges	Digital technology, network connection, spatial connection	• Constant Connectivity
Integrated	Balance of cultural, psychological, physical safety medical safety	User convenience, high accessibility	• Adaptable Classroom
Organized	Productive and effective environment for time and supplies	Shelving, storage, containers	• Project-based Learning
Flipped Learning	Teacher is the project's guide, presenting the problem to be solved, answering questions, and facilitating discussion	Flipped classroom, learn through hands-on activities, facility for working in teams	• Active Learning
Team Focused	Learn through hands-on activities and working in teams Support for encouraging learner participation and encouraging cooperation	Group Activities, Learning Process Sharing, Shared Space of Learning Outcomes	• Customized teamwork-space

3. CASE STUDIES OF STEAM LEARNING ENVIRONMENT

The ideal spatial design of a learning environment requires an educational approach that harmonizes learning objectives, concepts and activity spaces. From active learning classrooms to constant connectivity, educators can better engage students and improve learning outcomes. The goals of STEAM are problem-solving, innovative thinking, communications, productive teamwork, generating multiple ideas, and decision-making, so STEAM classroom design is to inspire students to think, innovate, prototype, and research in teams. Centered on project-based learning, an effective STEAM classroom fosters a positive culture that allows students to problem-solve, collaborate, create, test ideas, and build with their hands. For convergence education, a design strategy that can control the strength of physical contact and visual communication of learners by using the size, material, form, and structural characteristics of the space is required. According to previous studies, it was investigated that learning using an outdoor space has many advantages of outdoor learning, such as improving creativity and reducing stress [10]. it is possible to provide a learning environment that maintains the visual integration of the space and the originality of the area by zoning open spaces using corridors, walls, floors, stairs, architectural transparency, ceiling heights, and indoor and outdoor courtyards. Case studies were analyzed by classifying them into informal spaces for PBL, continuous connections for teamwork spaces, and adaptive classrooms for active learning according to spatial conditions.

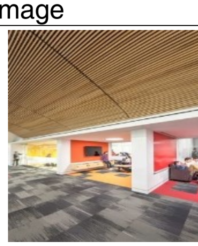
3.1 Informal Space for PBL

Table 5. Case Studies for Informal Space for PBL

School	Image	Design Features
Ecole Kenwood French Immersion, School (Columbus, Ohio, USA)		Fanning Howey designed the stairway has been extended to accommodate carpeted student seating and features an overhead projector, a large projection screen, a sound reinforcement system, and wireless access. The stairwell has transformed into a multipurpose space for lectures, presentations, collaboration, and socialization. The location of this area is a spot for lectures and student presentations as part of project-based learning (PBL).
Annie Purl Elementary School (Georgetown, Texas, USA)		The Huckabee architecture firm designed and installed floor-to-ceiling glass classroom walls to create an open and transparent environment. Each academic wing features classrooms that connect to a central collaboration space and a teacher design lab—enabling educators to see kids in the classroom, collaboration space, or corridors from virtually any spot in the learning environment

3.2 Constant Connectivity for Teamwork Space

Table 6. Case Studies for Constant Connectivity for Teamwork Space

School	Image	Design Features
Deerfield High School (Deerfield, Illinois, USA)		The principle of visual interconnectedness, and internal spaces like hallways, classrooms, and cafeterias have given way to open layouts that emphasize glass partitions and uninterrupted lines of sight. By removing a wall from breakout spaces, the school puts learning on display and makes it easier for teachers to supervise students working independently or in groups. Opening a line of sight into adjacent spaces makes learning communal, encourages collaboration, and creates a public forum for celebrating and observing student work, according to leading educational architects.
British International School (Huston, Texas, USA)		Fanning Howey constructed the entire building is wrapped around a common area called the Agora—Greek for “gathering place”—which is modeled on the public courtyards at the heart of city life in ancient Greece. All the classroom walls that surround the Agora are framed in floor-to-ceiling glass. The Agora uses the principle of transparency to allow younger students to see what the older students are up to. From this central gathering place, students can see and be seen, peering into others’ classrooms to view what they are doing while being observed at their work. Each classroom investigates and through the atrium at one another. Through visual transparency, the students and teachers are creating a public conversation about teaching and learning.

3.3 Adaptable Classroom for Active Learning

Table 7. Case Studies for Adaptable Classroom for Active Learning

School	Image	Design Features
Wagner Middle School (Georgetown, Texas, USA)		The school cafeteria is the heart of the campus, with a stage for performances and a stepped learning space for individual and group work. The flexibility of the space allows for rapid changes in the environment and creates educational diversity such as direct instruction, group work, and independent work to meet the daily needs of educators and learners. Light chairs, bean bags, rugs, tables of different heights, and even movable or collapsible walls can turn a niche into a quiet reading space, and can be modified for project-based learning or direct instruction.
Daugherty Elementary (Garland, Texas, USA)		The architecture and design firm Corgan created a learning courtyard that offers a variety of educational zones connected and a variety of outdoor learning zones connected to Texas standards. On the pavement, there are imprints of fossils native to Texas and Shadow walls teach students about the earth's rotation and seasonal cycles as shadows cast by the sun shift positions and lengths. A rainwater cistern enables students to track rainfall totals, while xeriscape landscaping—which requires little to no water—helps students learn about local, drought-tolerant plants and gain authentic experience with complex biological concepts like photosynthesis and osmosis.

4. DISCUSSION

First, informal spaces in STEAM-based learning environments encourage students to maintain lifelong learning in the fields of science, technology, engineering design, arts, and mathematics that are applied to a variety of environments and experiences. Informal spaces, including open lounges, private study spaces, outdoor spaces, coffee shops, etc., can be applied to the design of school common spaces. Reinforcing the enclosed single-use space connected to a long corridor designed to allow students to move quickly, and structuring the corridor to be used as an extended area of the classroom, or to use the seating stair space and the entire wall of the building for display and writing purposes. Ideal. Common disposable spaces such as cafeterias and libraries need to be designed to function as hybrid theaters, producer spaces and media centers. Second, broad and accessible technology for lasting connectivity is an essential feature of the STEAM classroom. Learners have a variety of devices, including tablets and laptops can connect to wireless networks. It should also have a variety of software programs, including virtual reality, that allow students to immerse themselves in hands-on learning activities in a professional environment. These design trends allow students the flexibility and mobility of education in and out of the classroom. The classroom book study space and practice are the same, so learners should be able to transition from lectures and discussions to hands-on projects without having to travel. Students need access to digital devices, so a microphone, sufficient sound projection, Wi-Fi, and a power supply are important. Like classrooms, outdoor spaces can be reserved for teaching, presentations, or independent and group work. Third, the possibility of flexible adaptation of the space can be expanded by overlapping spatial elements and utilizing flexible modular unit furniture and partitions. In order to induce learners to actively participate in learning, it is necessary to provide a physical flow, visual connection, and integrated space inside and outside the space. To this end, the variability and transparency of the unit space wall are used to create visual stimuli in the environment, it is necessary to expand the meaning of the learning environment, such as an outdoor space for group work.

5. CONCLUSION

Learning Environment based on STEAM Education requires informal space for PBL, constant connectivity for teamwork space, and an adaptable classroom for active learning. The flexibility and mobility of learning environment design suggests learners to easily collaborate on projects, including those that require access to the software or digital tools, meeting in groups to discuss a book, students need areas where they can plan, discuss, and troubleshoot projects. The adaptable classroom for active learning design encourages student engagement through activities and discussions for teamwork. The advantage of active learning spaces is that learners can face one another and participate in small group work. these areas feature round or oblong tables with moveable seating and the individual spaces in each area secure module variability and mobility with modular units for easy access between learning processes and learners, and secure contact between learning processes and learners. If the convergence education concept of integration and experience is reflected, the design of a learning space can provide a creative environment for learners. Such a learning environment will enable the fusion of logical thinking, discovery-based learning, hands-on learning and problem-based learning, and will support planned laboratory activities and contribute to the development of learning programs. As a result, it is possible to flexibly cope with project execution according to the contents of the class in the form of practice and collaboration. The flexibility of the physical space facilitates collaboration with team members to enhance understanding of other disciplines and to experience exchange of opinions.

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