Journal of Turkish Science Education, 2024, *21*(3), 599-618
DOI no: 10.36681/tused.2024.032

Journal of Turkish Science Education
http://www.tused.org
© ISSN: 1304-6020

A New Perspective on STEM Education: The Possible Contributions of Architectural Education

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ABSTRACT
Considering the structural similarities between STEM education and architectural education, it is thought that architectural education, which has a deep-rooted history, may be useful for improving STEM education. This research was planned to gain useful inferences for STEM education by trying to get to know architectural education. In this study, ethnographic field research method was used. During the four-week observations, students made presentations with projects, models and plan drawings. In this process, teachers' criticisms and students' defenses were analyzed through the data table. By discussing the identified elements of architectural education, at least six innovations and/or meaningful results were revealed in the context of STEM education. These are: i-Students should be given the opportunity to solve open-ended problems on their own and should be encouraged to learn through trial and error in this process. ii-Students should be highly motivated when dealing with open-ended problems, for example, STEM project courses should be turned into graduation qualifications. iii-The importance of real-life context in STEM education should be emphasized and problems should be a part of life; In this context, sustainability and economic value dimensions should be highlighted. iv- At secondary and primary school levels, children should be encouraged to learn by experiencing and manipulating materials in the context of problems. v- Courses that will improve technical drawing skills should be added to STEM education programs. vi- In STEM disciplines, teachers should ensure theory/practice balance at the undergraduate level, and evaluations in applied projects should be made by a jury system.

RESEARCH ARTICLE

ARTICLE INFORMATION

Received:
08.07.2024
Accepted:
02.09.2024

KEYWORDS:

STEM education; design studio; architectural education; culture of criticism; open-ended problems.

To citethis article: Özkan C, ÇepniS, MaratkyzyN, ArslanT V, DurakS(2024). A new perspective on STEM education: The possible contributions of architectural education. *Journal of Turkish Science Education,21(*3), 599-619. DOI no: 10.36681/tused.2024.032

Introduction

The prominence of STEM education as one of the most frequently discussed concepts in science education literature highlights its continued relevance in ongoing research (Tosun, 2024). Beyond the direct research conducted within the disciplines of science and mathematics education, theoretical and practical knowledge from other fields can also contribute significantly to STEM education. To enhance the practical aspects of STEM education, it may be beneficial to draw from architectural project education, which has a long-standing tradition as an alternative source of knowledge. The rich body of literature specific to architectural education can offer valuable insights. Researchers focusing on STEM education may derive useful conclusions from this deep-rooted knowledge in architectural education, potentially leading to further development opportunities for STEM education.

In this context, the research aims to draw on the valuable experiences from architectural education to identify ways to enhance STEM education. Before justifying this purpose and stating the research questions, the basic concepts of STEM education and architectural education were defined, and the results of a literature review on studies exploring the connections between these two fields were presented.

Theoretical Framework

Under this heading, STEM Education, Project-Based Learning approach, as well as some concepts that are thought to enable educators to understand project design education in architecture to some extent, are explained based on the relevant literature.

STEM Education

STEM education, aimed at cultivating human resources capable of problem-solving and technological development in a competitive global environment, has been a focus of educational discourse (Çepni, 2023; MEB, 2018; MEB, 2019; Yıldırım, 2018). Known for fostering 21st-century skills like collaboration, communication, critical thinking, and creativity (Bayraktar, 2015; Karataş, 2017; Rahmawati et al., 2021), STEM emerged in the USA during the 1990s, emphasizing the importance of science, technology, engineering, and mathematics in technological competition. Over time, the inclusion of art led to the evolution of STEM into STEAM, addressing gaps in creativity and innovation (Chung, 2014; Özkan, 2020). Among various pedagogical approaches in STEM, project-based learning (PBL) is particularly effective, aligning closely with STEM's emphasis on real-life problem contexts, creativity, and iterative design processes, though it does not explicitly integrate all STEM disciplines (Habók & Nagy, 2016; Norazla et al., 2016; Wieselmann et al., 2022).

Project-Based Learning

The Project-Based Learning (PBL) approach, developed on the basis of Dewey, Kilpatrick and Bruner's ideas on learning, arises from the constructivist learning theory (Bayraktar, 2015). PBL is described as an educational approach in which students explore real-life problems, conduct research, pursue knowledge, collect and analyze data, create opportunities to design products, and construct knowledge through experience. Through PBL, students gain self-confidence by goal setting, planning, and organizing. They also improve their collaboration skills through social learning and motivation through self-selection opportunities (Kokotsaki et al., 2016). Learning is context-specific in PBL. Thus, learners actively develop their understanding by engaging in real-world problems and achieve their goals through social interactions and sharing. In other words, PBL is a learner-centred, teacher-supported educational approach that transcends the boundaries of curriculum subjects and relates learning to the real world (Baran et al., 2021; Haatainen & Aksela, 2021). It is known that PBL has many difficulties at school level with respect to teachers, students, and school conditions. However, effective implementation of PBL in the classroom depends largely on the teacher’s skills (Haatainen & Aksela, 2021; Ladachart, et al., 2022; Morrison et al., 2021; Wieselmann et al., 2022).

Design

Design refers to the decision-making process of an individual tasked with solving problems. The design process begins with a verbal or written expression of the person about the problem solution (Bayramoğlu et al., 2019; Kapkın, 2010). Creativity in the design process can be expressed as a leap from the problem situation to the solution. There is no specified method of creativity, and not every design process results in creativity (Demirkan & Afacan, 2012; Yurt et al., 2020). Creativity process in design emerges itself through the stages of preparation-incubation-enlightenment-testing. Designing is not a linear process, but a feedback-driven cyclical development process. The expectation of "the single best solution" in design represents the master-apprentice relationship. For the apprentice, the master represents perfection. However, real life progresses with satisfactory solutions (Ciravoğlu, 2001).

Architectural Education (Design Studio)

Schooling in architectural education started with the Academy of Architecture in France in 1671. Designs on paper were first implemented in this school. The educational methods used by this school were very close to the studio education seen in architecture faculties. Students are given design problems, their work is criticized by juries, and supported by competitions. This educational tradition was developed at the beginning of the 20th century with the Bauhaus school, partly by emphasizing individual creativity (Akyıldız, 2020; Ciravoğlu, 2001). Today, the design studio is the center of the educational life of architecture students (Pasin, 2017). Criticizing the students' design ideas by the instructors in the architectural design course (studio) is seen as the basic pedagogy of architectural education. The studio is not like the classroom layout in undergraduate education of other disciplines, but rather like a workshop where students spend a lot of time (Aykaç, 2021; Oh et al., 2013). Students can receive criticism from their teachers several days a week about the solutions they produce to design problems, and also benefit from other students' works and criticisms made on them. The system aims to develop students' spatial thinking and problem-solving abilities by confronting them with real design problems, providing them with critical thinking skills, to acquire professional knowledge, and to provide them with the ability to solve concrete problems through abstract thinking.

In this education process, the ability of hand and mind to work together develops, as in art education (Hettithanthri & Hansen, 2022; Yılmaz & Ulusoy, 2016; Yurt et al., 2020; Yüksel et al., 2021). The design studio is based on learning by doing. Architecture candidates have to learn the design process, which they do not yet know, on their own through a project (Ciravoğlu, 2001). Design can only be learned by doing it oneself. The concepts of knowing in action and reflecting in action come into play. It is an important challenge in the first year of design education for students coming from the traditional teacher-centered education system to give up these habits and develop their abstract thinking abilities and creativity. (Akyıldız, 2020; Yurt et al., 2020). Instructors' critiques are named according to the environment; such as table criticism, group criticism, intermediate jury criticism, and final jury criticism.

The method of teaching lessons in the studio is basically a teacher-student dialogue that takes place at the drawing table, where the teacher criticizes the student's thoughts. Due to the one-way flow of professional information in this communication and the inability to discuss the teacher's views, the teacher-student relationship is likened to the master-apprentice relationship (Ciravoğlu, 2001). However, it should not be overlooked that criticizing student's work is a developmental process that results in the students first defending themselves and then correcting their work.

Technical Drawing and Visual Communication

Drawing Techniques have a fundamental place in expressing architectural project ideas. Such skills of students are developed with "Design Geometry and Technical Drawing" and "Perspective" courses. Technical drawing is a narrative language through lines and is the main communication tool in presenting ideas in technology education. Being able to draw physical entities to scale is related to the individual's spatial thinking skills. The lack of courses aimed at developing such thinking skills in undergraduate education results in students who come to study architecture experiencing great difficulties in their first years (Bilgiç & Konak, 2016). Graphics, which has an important place in effectively conveying architectural ideas, is a more encompassing concept. Graphics are the meaningful development of an entity by isolating its photographic form from its details, in the context of the idea to be conveyed. Symbols, icons, emblems, logos, etc. can be given as examples (Ersan, 2022).

Literature

A study based at Tufts University examined how hands-on educational activities can promote engaging learning. The aim of the study is to understand how all stakeholders in the learning process learn from the identification of a problem to its solution. Within the scope of the project, a technique combining novel and engineering practices was used. In this technique, students read a book, use their engineering skills to find solutions to the challenges faced by the heroes in the book, and are asked to see themselves as engineers. Thus, students face processes such as problem solving, gaining new skills and sharing experiences. Tufts University academics state that by using this method for two years, they have developed a powerful educational tool that combines different fields such as social sciences, CEIT, STEM and maker education. Research provides experiences and guiding principles that make engineering engaging (Gravel et al., 2018).

You, Chacko and Kapila's (2021) study addresses a professional development (PD) programme designed to support secondary school teachers to integrate robotics into science and mathematics lessons. Teachers participated in this PD programme for three weeks (15 sessions, 8 hours each) at the NYU Tandon School of Engineering. The programme has been structured by experts in engineering and science education with course materials, robotic sample lessons and robot activities to ensure the active participation of teachers. Findings indicate that the programme was effective in increasing participants' robotics knowledge, confidence, and ability to integrate robotics into teaching practices. Teacher reflections and follow-up interviews provide guidelines for the development of technology-supported science and mathematics teaching.

In their study on Professional Development (PD) for Educational Robotics (ER)-based STEM education, Çepni et al. (2024a) investigated the effect of the ER STEM PD course based on a modified P3 task taxonomy on teachers' STEM knowledge. Twenty in-service teachers attended a 24-hour PD program using Arduino kits, creating lesson plans, and completing tasks. Pre- and post-tests showed significant improvements in robotics (2.08), science (1.49), and mathematics (0.92) knowledge. The results suggest the P3 task taxonomy is an effective approach for PD in ER settings, surpassing traditional methods like the 5E model and project-based learning.

Çepni et al. (2024b) conducted a qualitative on the premise that educational robots (ER) provide a problem-solving environment for prospective teachers that requires content knowledge and practical skills. In the study, the problem-solving strategies used by nine science teacher candidates who were assigned to build a methane gas detector in the online robotics integrated earthquake PD course were examined. Data obtained from, observations and interviews were analysed. The results showed that participants mostly used trial and error, expert opinion, and case-based reasoning, but rarely resorted to heuristics and intuition. The study also developed a comprehensive framework for understanding problem solving in ER contexts.

Chance et al. (2013) discussed the reflection of architectural education background, which they describe as project-based learning pedagogy, to engineering education. According to them, engineering programs similar to design studio education that force students to think outside the box are becoming widespread in the USA. They pointed out that similar techniques are used in medical and art education. They went further and argued that this model is "one of the best learning and professional development systems that can be designed" for all higher education majors. In their proposed approach, students are asked to work in groups of three to six people. Groups are confronted with problems in which they must go beyond their current knowledge. They are expected to discover the problem situation. Groups are expected to complete a cyclical process of brainstorming, self-learning, and reporting.

Ylirisku and Filz (2018) examined the differences between engineering and design education. In their research, they benefited greatly from Donald Schön's books "The Reflective Practitioner: How Professionals Think in Action" (1983) and "Educating the Reflective Practitioner" (1987). According to the authors, Schön expressed professional practices in two ways, namely t*echnical rationality* and r*eflection in action*. The idea of Technical Rationality was reflected in school curricula in the 1970s. Accordingly, the scientific essence must first be learned and then applied. Thus, theory is hierarchically superior to practice. The authors similarly demonstrated such problematic separation between theory and practice through their study of an engineering school curriculum. According to the authors, *reflection in action* emphasizes the epistemology of practice, which implies creative solutions that practitioners bring to situations of uncertainty, instability, uniqueness, and value conflict. Architecture studios have been considered to teach reflective practice. In the article, the authors include their observations on engineering projects and then list the characteristics of design education. Engineering students find open-ended real-life projects very disturbing and troublesome. Students are kept safe in an educational environment where they can learn basic skills and where the answer to every question is clear. Students solve problems with ready-made tools and techniques. This is indeed in line with the perspective of Technical Rationality stated by Schön. The authors gave the characteristics of design education as a framework for reflection in action. Finally, in the research, the necessity of constantly reviewing the problem situation, the fact that design is a learning process, and the necessity of destroying existing judgments that hinder creative design are presented as remarkable dimensions to understand the unique nature of design.

Tovar et al. (2018) examined how art pedagogy can be used in engineering education. In their paper, the authors developed the multidisciplinary engineering, technology and arts (ETA) education model for mechanical engineering education. The relevant elements of the education model, are that it includes hands-on learning, multidisciplinary design projects, and interaction of engineering students with art students. The expected goal of this model is to advance aesthetically technical innovation in engineering students. The proposed ETA model has been implemented in graduate courses. These courses include practical learning techniques with a problem-based, studio approach and a balanced mix of pedagogical methods consisting of engineering, technology and art.

Schnittka et al. (2012) examined the motivation created by the studio model in out-of-school engineering education experience. The authors stated that STEM education is becoming more visible in out-of-school environments such as summer camps and club organizations. Additionally, they pointed out that the majority of Nobel Prize winners in science first gained their passion for science in out-of-school environments. In the summer camp organized within the scope of the research, young people are given the role of engineers and asked to design better insulating building materials that can reduce energy consumption in the fight against global warming. In the created studio STEM design environment, participants were given the opportunity to experience and learn the thermal properties of various building materials, from paper to polyester, before the design and testing phase. After they were introduced to the concepts of heat transfer, conduction, convection and radiation, the design process began. As a result of the research, it was revealed that the studio STEM environment supports students' learning, makes them feel successful, increases their interest in engineering, science and computer science, and provides interest and motivation.

Based on the effectiveness of the Arida (2011) design studio in creative thinking, it was possible to implement a similar programme in a private high school in Boston. This programme, called NuVu (New Vision), educates students by focusing on multidisciplinary studio projects instead of traditional teaching methods. The programme aims to prepare students to solve today's complex problems and to raise a more creative generation. The programme operates on an 11-week trimester system and focuses on different themes each semester. As a result, students are involved in a creative process in which many ideas are generated, tested, modified, and tested again. The official launch of the program after the pilot implementation and the voluntary work of students on the projects show that the program was successful. This example shows that the principles of architectural education can also be used in STEM education (Arida, 2011; Gavra, 2015).

Idawati et al. (2018) argued that the STEAM approach in science education should start at a very early age to attract children's attention to science, technology, engineering and mathematics. One way to develop future interests in STEM is by using architecture in science classrooms. Many kinds of architectural shapes, sizes, and spaces have been experienced, prompting them to question what architectural design is. For this reason, the world's most well-known mega structures such as Borobuyor in Indonesia, the Taj Mahal in India, the Great Wall of China, the Twin Towers in Malaysia and other monumental structures of the world are also introduced. When children have basic knowledge about architectural structures, they can first imitate them and then design their unique structures using their digital skills. In this way, they can develop positive attitudes towards STEAM professions such as Architecture.

Aim of the Research and Research Question

Educational spaces called studios in architectural education are quite different from the traditional classroom environment. While the classroom environment is designed to transfer knowledge to young minds in the most efficient way, the design studio is like a workshop where knowledge is gained by doing. Project activities in STEM education differ from classical lessons in the classroom. It can even be said that the classrooms resemble studios during project activities. In STEM education, students are expected to encounter real-life context experiences. STEM skills are inherent in life learning. Because we use STEM skills such as critical thinking, interdisciplinary perspective and knowledge acquisition while coping with daily challenges (Jorgensen, 2017). Architectural education also exhibits an approach based on real life context. Therefore, it can easily be said that the basic qualities of STEM education and architectural education are similar to each other. In this context, knowledge embedded in architectural education can be transferred to STEM education with logical inferences. The basic assumption of this study is that the stated analogical inferences can transfer knowledge to STEM education. There are no studies in the literature on the effect of architectural education on STEM education. In this sense, it can be said that the article will fill a gap in the literature and raise awareness about the relationship between two disciplines that have not been associated until now, namely architectural education and STEM education.

The purpose of this article is to obtain new and/or meaningful results about STEM education by making observations in architectural education classes, to obtain knowledge and develop judgments about architectural education, and to make analogical inferences.

Research Question: *What are the prominent elements of the architectural design education method applied in the first year at BUU Faculty of Architecture?*

Methods

Ethnographic research method was preferred to find answer to the research question. This qualitative research method was used in order to reveal how students learned to design. Elements of architectural design learning were evaluated comprehensively and information about STEM education was obtained through analogical inferences. At this point, we point out that the data collected from an area of architectural education by ethnographic method is not evaluated for the purpose of a new invention in architectural education. Whether the findings bring an innovation to the architectural literature is a separate matter of debate. In this study, the findings obtained were used to produce new and/or meaningful information in the field of STEM education through logical inference.

Ethnographic Research Plan

In ethnographic research, the researcher collects information by entering into that community and acting as a member of that community (participant observation) in order to obtain in-depth information about the community of interest (Çepni, 2021). The classroom environment of Architectural

Design Courses at BUU Faculty of Architecture was chosen as the research community for the purpose of this study. This course aims to give basic information about the architecture and design process and to provide students with analytical thinking, analysis and problem solving skills. In addition, it is aimed to provide students with key concepts such as proportion, scale, aesthetics, form and function relationship. The architectural education classroom environment is different from the formal education tradition. Architectural Design is taught in a studio environment. In order to become architects, students receive studio project design training as a high-credit course (8-10 hours per week) for 8 semesters. The first author, a researcher in the field of science education, directly attended architectural design classes and made in-class (studio) observations. Thus, students' presentations of their designs and how teachers criticized them were observed in the studio environment. Later, interviews with students were also used for data verification. Considering the data obtained through observations of how prospective architects acquire architectural design/project skills, the information was compiled through content analysis and transformed into findings.

The researcher was introduced to the students as a person who wanted to get to know architectural education closely because he was considering becoming an architect. In this way, the students, who were the main observation focus of the observer, were prevented to some extent from feeling like they were being observed, and the naturalness of the environment was tried to be ensured. The course was followed for a semester and observation notes were taken for 4 weeks. The class size consists of 30 students. The research data was obtained from the notes taken by the observer in her notebook about the attitudes of the students who received criticism from their teachers during the lesson, how they defended themselves, and how their teachers criticized them. In order not to affect the environment and not to miss any details that could be gained, the observer did not participate in the in-class dialogues, did not ask questions, and maintained his passive position.

The first semester of the first-year students of the faculty of architecture was preferred, considering that it would provide more appropriate information for the research. The first semester is the most appropriate semester to observe how one adapts to the transition from high school education focused on solving multiple-choice tests to an education system where a problem does not have a single answer and has more than one solution. Choosing a period in which the students' knowledge of subjects such as architectural concepts, architectural design problems, and different design approaches has just begun to form, they do not yet have sufficient experience in solving design problems and they do not have prejudices, was preferred considering the purpose of the study.

Data Collection Tools

Considering the research purposes and the fact that the observer was not an architectural education expert, unstructured observation technique was used as the main data collection tool. In other words, a structured form was not used, but notes were taken effectively throughout the observation period. After the lesson, the notes were transcribed without delay and the observations were converted into report format. The teachers of the course, who are experienced professors of the faculty of architecture, are also the 4. and 5. authors of this research. The notes taken by the observer were shared with the course instructors because they included concepts related to the field of architecture expertise. Thus, misconceptions were checked and the validity of the data was tried to be ensured. At the end of the semester, 8 randomly selected students, all volunteers, were interviewed. Although the interview data was used for a different research purpose, the validity of the research was strengthened by comparing it with observation data. The interviews aim to reveal students' perceptions of the architectural design course rather than directly answering the research question.

Validity and Consistency

The analyzed texts of the observation reports and interviews were arranged, and the data obtained was systematically analyzed. The texts were read carefully, and their extracts were coded.

Categories were determined from the codes. Then, inferential themes were reached through the analysis of the categories. Codes, categories and themes were created by the first author. The final structure was created after the other authors examined and evaluated the results of the analysis. Besides, the Theoretical Triangulation Method was employed to ensure the validity and consistency of the research by comparing the findings obtained by researchers with known theories (Çepni, 2021). When the findings were completed, it was evaluated that they did not contradict the information in the literature. Students' verification of interview texts and the use of more than one data collection tool are factors that contribute to ensuring validity.

The factors that determine the validity and reliability of the study are followed; i- There is information in the literature about how architectural design is learned. It has been observed that the findings obtained in this research do not contradict the information in the literature. ii- It was also determined that the findings of the interviews with the students were compatible with the observation data. iii- The fact that the second researcher is an expert in the field of science education research in terms of method and application knowledge strengthened the theoretical framework of the research. iv- The knowledge and experience of the fourth and fifth authors in architectural education supported the accuracy of the data and the consistency in the evaluations. v- The first three authors, who are science education researchers, contributed to the creation of the conceptual and theoretical framework and the analysis of the data. vi- When the findings of similar studies given in the literature section are tabulated in a document analysis, it is shown that they do not contradict the research findings.

The content summaries of the research shared in the literature section were subjected to document analysis and compared with the themes obtained as a result of the content analysis of ethnographer field research data. Below is the document analysis result matrix created by five studies (Table 1).

Table 1

Categorical classification of similar research (Document Analysis)

	i- Confronting open-ended problems	ii-Deepening understanding of the problem situation	iii- Gain experience in presentation techniques	iv- Meeting the Culture of Criticism
Chance et al. (2013)	Self learning Reflection in Action (open-ended problems)	self learning Reflection in Action (open-ended problems)	Reporting processes	Thinking outside the box
Ylirisku AND Filz (2018)	Reflection in Action (open-ended problems)	Constantly reviewing the problem situation		Designing is a learning process Breaking existing judgments
Tovar and et all (2018)	Multidisciplinary design problems			
Schnittka and et all. (2012)	Building material design	Experiencing the properties of materials		

Arida (2011)	Multidisciplinary studio projects	Exhibition of projects	Generating ideas, testing, changing and retesting

When Table 1 is examined, it seems that it makes sense to bring together concepts such as self-learning and reflection in action, multi-disciplinary design problems and practices such as building material design, and expressions such as studio projects, under the title of Confronting Open-Ended Problems. Under the title of Deepening Understanding of the Problem Situation, it seems that bringing together the expressions of experiencing the properties of materials along with steps such as discovering the problem situation and constantly reviewing it provides meaningful integrity. It can be stated that similar combinations are meaningful for other headings as well.

Results

Results from Observations

Students who are given a design problem in the architectural design course, just like an architect, research the solution to the problem and prepare drawings throughout the week, present them to their teachers in the studio and receive criticism from them. The students of the observed course were shown 5 plots of land in the city center to make designs. Since the class size is 30 students, there are 6 students per plot of land. Students have the opportunity to receive critiques from their teachers twice each week. Students are always asked to express their ideas through visual means; plan sketches, photos, storyboards, etc. This process continues for weeks so that the projects submitted by students mature to meet the design problem. The first observation was made on 01.12.2022, the second observation was made on 8.12.2022, the third observation was made on 15.12.2022 and the fourth observation was made on 22.12.2022. Although there were 30 students in the first observation, only six students explained the project concept themes. In the second observation, model presentations were made, and in the third week, presentations were made with models and plan drawings. In the fourth week, students were seen hanging storyboards, concept sheets, sketches, and plans on a board in front of the jury, this time using all presentation techniques. They made a presentation with 1/50 and 1/200 models with them. Project evaluations were carried out with the participation of an architect in addition to the course instructors on the jury. Reports were created regarding observations made in the studio environment for 4 consecutive weeks. Most of the texts consist of students' presentations and teachers' critiques of them. As a result of the analysis, the data is presented in Table 2 in the form of categories, and themes and enriched with typical quotations.

Table 2

Observation findings on architectural design course learning methods

Themes	Categories	References from observation notes (Codes)
Facing with the open ended problems,	Student Motivation	He finds the circular design interesting, but explains that for a good evaluation 1/50 architectural sketch plans are needed. She said that it is actually important to include the deaf wall on the neighboring parcel of the building in the design and to hang the spaces in a gridal system and that this is a brave approach...
	Thinking out of the boxes	The teacher breaks the student's model and forces them to go out of the mold. The lecturer tries to reorganize the model by dividing it with his hand... The lecturer explains to the student that what is being done is trying to generate ideas based on

		personal experiences. ... Another student explains that he lives in Balıkesir and that there is a youth center there and that he was inspired by it... When he tries to generate ideas based on personal experiences, the teacher shows personal stereotypes and raises awareness about stereotypical perspectives and states that it is necessary to go beyond the stereotype.
Deep thinking on understanding the problem	Suggestions on finding various solutions on the problem	It was suggested to think about more contemporary digital games instead of the game activities that the student wants to put in his/her needs program. Video mapping artist Refik Anadolu gave an example. He stated that the artist's exhibition is still going on in Beyoğlu Alkazar in Istanbul, he stated that he should examine the works of Muse VR and think about games such as HADO... The lecturer stated that in order to design, the experiences of previous architects are important and that reading should definitely be done. He repeatedly emphasizes the importance of preliminary studies, reading and watching similar works. The lecturer asked to read Rasmussen's book "Living Architecture".
	Emphasizing making in depth research	He stated that no mother would leave her child in such a social center unless she was very sure that it was safe. . The lecturer asked the design student to research the design criteria and safety aspects of children's playgrounds.... The lecturer told another student that Ebru and oil paintings on canvas can be done in the space he designed. However, while designing this, he asks if you ever thought that the materials produced for these processes would have heavy odors... He talks about the importance of concepts in knowledge areas such as physics, mechanics, vectors for rationalization, giving an example of the relationship between cantilevering and moment in the structure. He explains the necessity of designing by considering even the ease of manufacturing by the master...The lecturer stated that it is not possible to design without considering the costs and difficulties of the skylights created, and that the benefits behind them must be expressed strongly...
	Strong arguments for design ideas	How would you convince employers to make this design that you are thinking of realizing, would you be convinced by your own explanations, seeing yourself as an employer? You have to weigh this yourself.
	Students need to Make field reseach	In their presentations, the students emphasized the need to go to the land to explore the physical and cultural characteristics of the land they will design on and to conduct research on the needs of the neighborhood by meeting with the mukhtar or neighborhood residents. In response to this, the students said that the mukhtar stated that the biggest problem of the neighborhood is the lack of parking... In addition, regarding the issue of researching the demographic structure of the neighborhood, Veledi stated that there is a nursing home opposite the Mosque.
Gaining Experience in	Portfolio File Preparation	The lecturer explained the need to prepare a portfolio file, starting from the first day, all the work in the form of sketches,

Presentation Techniques.		photographs in the form of design stages in the best way to reflect the need for a filing. The importance of including all the works during the semester in this portfolio in terms of monitoring the student's development was conveyed....
	Presentation technics	Students reflected the work behind their ideas by showing that they used techniques such as synthesis sheet, storyboard, bubble diagram while explaining their ideas.
Meeting the Culture of Criticism	Demonstrating Spatial Errors in the Design Idea (Teacher Statements)	Considering the building dimensions, it seems that the designed bowling alley cannot be accommodated..When the teacher examined the model in detail, he noticed that the floor height in some places was almost 1.5 m. It was emphasized to the student that the floor height in residential and similar areas should be at least 2.60 m, and that the floor height should increase as the width and length of the area increases…the teacher asks how to get to the kitchen part., it seems that there is a very narrow area left for the passage due to the stairs, and the head of the passerby will be hit... The teacher explains that the door movements of the WC cabins are not considered and if the door is opened, it hits the toilet bowl... Considering the elevations, it is seen that there will be a retaining wall at the bottom of the building, approximately 4 m long. he stated.
	Questioning the Design Idea and Highlighting Its Deficiencies	He states that the necessary evaluation was not made, for example, he asks what functions were considered in the interior spaces, is there a need for 4 floors? The teacher now asked how many centimeters away he could bend down and work. He questioned that it was difficult to work even one meter away and even if he did, how many minutes could he work in such a tilted position... After examining the plans and models, the teacher questioned why this was built as a blind wall since there was no adjacent wall on which the building was based... The teacher needed to pay attention to the greenhouse effect of such large glass spaces. He stated that it would create completely different difficulties in terms of comfort… The teacher explains that it is very difficult to make a door leaf wider than 120 cm and that the hinge systems do not support them… ..he stated that the hobby area reserved for the elderly on the ground floor is very small, it is an area where two people can hardly fit.
	Emphasis on Professional Knowledge and Skills	He said that spaces should have a hierarchy, and you should take these into consideration in your designs such as reception areas, changing rooms, play areas, etc... He explains his relationship with the world... He stated that people have physical dimensions and psychological dimensions.

Table 2 shows the findings obtained as a result of the content analysis of the texts of student presentations and observation notes regarding the criticisms teachers gave to students. Accordingly, 4 themes were determined with possible groupings of categories. It is thought that these determined themes will reveal the general framework of learning in the Architectural Design course. To better understand the categories specified in the table, quotations of the trainers' criticisms have been specifically reproduced.

Interview Results

What do you think is the purpose of the Architectural Design Course? There is a category of findings from the answers given to the question that the purpose of the course is to increase conceptual thinking skills. Student expressions representing this category are shared below:
S2....is making abstraction
S4....encourages us to make more original, modern structures by dealing with abstract concepts
S5....allows us to look at life in an abstract sense
S6...abstract thinking
S8....we see something in another lesson and apply it here, the basis of architecture

Two questions were asked to reveal students' perceptions of the difficulties of the course, and the difficulty categories revealed as a result of the analysis of their data are listed in Table 2.1. Quotations from student expressions regarding the "difficulty of the invention process" are shared in Table 2.2.

Table 2.1

Challenges perceived by students

a-	Difficulty in Model making	S1, S7, S8
b-	Expectation of perfection	S1
c-	lack of time	S1, S5, S7
d-	lack of motivation	S1,
e-	difficulty in hand drawing	S3, S4, S5
f-	Difficulty in making presentations	S3,
g-	Difficulty in the invention process	S2, S3, S6, S7,S8
h-	Difficulty in carrying the model	S8

Table 2.2

Student statements on the difficulty of the invention process (Codes)

S2.... I make a mistake and then I think of a better design. Then I think of something better again and it still doesn't work, so I keep redrawing it. Design from the beginning and make a model. S3....we have to do research all the time because it is something we do not know. S6....to be honest, we have to make our professors like us, because there is no concrete truth, we have to change all the time. S7....we designed something called an experiential space. I misunderstood it at first, there was a misunderstanding, I know I didn't leave for two days, I know I cried from stress, S8....thinking about something you would do in one day, you think about it for three days, four days, this process is a bit tiring, there can be a lot of things in your head, sometimes nothing at all. But on the bus, at home, you know, it's like that, I realized that especially after this last homework, your life becomes like this, you think about it on the bus, you go home, you think about it, you eat, you think about it. After you've found it, you feel a bit more relaxed, but until then it's always in your head.

Discussion

The answer to the research question has been revealed with the themes obtained from the content analysis of the data obtained as a result of the ethnographic field study (Table 2). Discussing these themes in terms of their possible contributions to the architectural education literature is not the subject of this article. In line with the purpose of the research, the findings were evaluated and possible contributions to STEM education were revealed through analogical inference.

Analogical inference is a type of logical thinking based on an analogy. It is widely accepted that analogies play a role in intuitive discoveries. An analogical inference is formulated as follows: If a system or part of it is similar to another system or part of it in certain aspects, the features discovered in the first system are also present in the second system, or these features are said to be similar (Bartha, 2024). The rules for the reliable use of analogical arguments are as follows: As the similarities between two fields increase, the analogy becomes stronger, and as the differences increase, it becomes weaker. As knowledge of the field decreases, the analogy becomes weaker. Analogies involving causal relationships are more plausible, and structural analogies are stronger than superficial ones. In addition, the suitability of similarities and differences to the conclusion is important, and multiple analogies supporting the same conclusion strengthen the argument (Bartha, 2024).

The discussion will be carried out by addressing four main themes one by one regarding how architectural design education is carried out. Each theme will first be interpreted by establishing a relationship with the literature, and then discussed in detail to draw conclusions about STEM education.

Self-Learning

Facing open-ended problems, (Radical Change in Learning Habits): In architectural education, students face real architectural design demands starting from the first semester with design courses. This method is compatible with the historical background of architectural education (Pasin, 2017). Students are expected to solve open-ended problems that they have not encountered before. This requires a radical change in learning habits in the first year of architecture school (Öksüz & Demir, 2018). Students have to solve these ambiguous and challenging problems on their own, and this process pushes them to creativity and intuitive solutions (Ciravoğlu, 2001; Ylirisku & Filz, 2018). Similarly, in STEM education, students are expected to deal with real-life problems and produce solutions.

Solving a problem encountered for the first time emphasizes problem-solving ability, which is a sought-after competence in the business world (Bayraktar, 2015; Rahmawati et al., 2021). In architectural education, students are expected to solve problems on their own. This process is challenging. Architectural education is like a simulation method that reflects real life. Students are allowed to make mistakes and are expected to learn from those mistakes. The first conclusion that can be drawn in this context is that in STEM education, students should be given long-term opportunities to solve the problem on their own from beginning to end.

Design education difficulties of architecture students are frequently mentioned in the literature (Akyıldız, 2020; Yurt et al., 2020). Students have two main supports in dealing with these challenges: professional motivation and the dedication of faculty members. In-class observations reveal the patient efforts of instructors to correct students' mistakes (Table 2). Giving students choice opportunities in STEM activities can provide motivation (Kokotsaki et al., 2016), but it is difficult to say that this is sufficient. On the other hand, radical innovations are needed in STEM education. As a radical suggestion, one might consider denying a high school diploma to students who cannot complete an applied project. Arida's (2011) NuVu experience can provide evidence of the project capability of high school students.

However, it does not seem meaningful to tie graduation to a project at the K4 and K8 levels. At these levels, activities focusing on the problem situation rather than STEM projects may be more appropriate. A second conclusion that can be drawn under this heading is the suggestion to radically enhance the value of STEM projects in real-life contexts at K16 and K12 grade levels to ensure higher motivation, and to revise programs accordingly. At K8 and K4 grade levels, however, STEM activities that focus on problem situations appear to be more meaningful.

Deepening Understanding of the Problem Situation

Students are given the task of designing a building that will meet the needs of the district on a plot of land in the city. It is emphasized by faculty members that the design must have strong arguments. Identifying the problem requires research; Students determine needs by both examining local characteristics and interviewing local people. Lecturers often state that students should benefit from the experiences of previous architects and not make presentations without sufficient research. The fact that students solve design problems in this way shows that architectural education overlaps with the problem-based learning approach.

In architectural design education, one of the issues that faculty members criticize is how deeply the problem is examined. This approach overlaps with Problem Based Learning (PBL). In PBL, expressing the problem strongly contributes to the development of scientific process skills and science literacy (Söyleyici, 2018). However, PBL keeps the student at a cognitive level and does not direct them to a product (Semerci, 2005). In architectural education, investigating the problem situation starts with going directly to the field (Table 2). At K4 and K8 levels, two inferences can be drawn from the architectural education background: It is the student's identification of the problem related to his/her life *(i)* and physical contact with the nature of the problem *(ii)*.

i- Authenticity of the Problem (Benefit Principle): In the architectural design course, students are assigned with a real project directly in the field. A real problem like this should be addressed in STEM education. Although there are statements in the science education literature that the problem should have a real-life context, this is generally not achieved in practice. The problem should be part of the student's life. There's a difference between an unowned problem and a real problem. The real problem includes the dimension of sustainability and value, this principle is also included in the definition of design (Kapkın, 2010). A century ago, John Dewey applied pragmatism to education, advocating being in production and learning by doing (Bender, 2005). İ.Hakkı Baltacıoğlu called this the principle of benefit (Özkan, 2012). However, this principle is almost absent in today's school practice. When the secondary school project subjects applied to TÜBİTAK are examined, it can be seen how far the projects produced by our education system are from the principle of benefit. For example, "Should Sunflower Oil or Corn Oil Be Used for Fries?" A project like this seems like a problem for the teacher or parent rather than a problem that a middle school student can grasp. Such unowned problems remain only at the cognitive level and do not develop real problem-solving ability, which is the goal of STEM education. There are many examples of such attached problems in TÜBİTAK projects (TÜBİTAK 2022). The problem the student chooses must have an aspect that belongs to his reality and leads to a value. In this sense, focusing the student on his problem carries us to high-level scientific process skills SCI education (Aydoğdu et al. 2012). This alone can be said to be one of the benefits of STEM education. Raw problem ideas that the student can capture, that is, real problems, should be the focus of STEM education for lower grade levels such as K4 and K8. The problem in architectural education is very simple: responding to people's functional building/space needs. However, when a secondary school student is asked to determine a project problem for himself, he falls into a very broad field. At this point, STEM activities should be planned to focus on the problem situation under the guidance of the teacher. The teacher's role here is to criticize students' opinions using similar methods as in architectural education. In Table 2, the criticisms given by the faculty members in the category of emphasizing the questioning deficiencies of the Design idea and the need for in-depth research reflect exactly this. Instructors should draw the student to the desired problem situation with questions that can be beneficial. In the end, even if the student poses a genuine problem of his own, he will probably not be able to progress to a product at his grade level. Ensuring the authenticity of the problem is the third recommendation that can be derived from architectural education.

ii-Contacting the physical dimension of the problem: In the architectural design course, students go directly to the field and conduct investigations to analyze their problem situation. Similarly, in STEM education, physical contact should be established with the object of the problem. The fact that a product cannot be produced in STEM education at K4 and K8 grade levels does not mean that the student cannot physically interact with the problem situation. Otherwise, as in the problem-based learning approach, this will require students to keep their studies at a cognitive level (Semerci 2005). However, as reflected in the ancient achievements of architectural design, learning in action can be implemented within these grade levels (K16) (Akyıldız, 2020). Therefore, depending on the topic of the problem, students need to transcend the cognitive domain and be carried away by the physical nature of the problem by touching related objects. For example, let's assume that a student has adopted the "Solar Panel that Follows the Sun" project and wants to do it. In reality, it seems difficult for secondary school students to complete such a project with the principle of benefit. Even in this case, students should come into contact with the solar panel within the scope of their projects, experience how the electricity it produces changes according to the inclination of the panel surface to the sun, be able to change the angle of the panel on their own, observe the results, and be able to see and measure what changes occur. So, the fourth conclusion that can be drawn from the accumulation of architectural education is that children in K4 and K8 classes get to know the materials and tools related to their projects by experiencing them firsthand.

Technical Drawing and Graphic Communication

Gaining experience in presentation techniques: In the architectural design course, students have to present their work to the lecturers and this is used as a basic communication tool in the studio. At the beginning, students express their ideas with visual tools such as scale-free synthesis sheets, concept maps and storyboards, and as they progress, they use techniques such as scale models, plans, sections and perspective. Graphic communication is more effective than written language, especially in conveying three-dimensional ideas. However, inadequate teaching of spatial thinking skills in pre-graduate education makes it difficult to learn visualization techniques in the first years of architectural education. This situation is also reflected in the students' perception of difficulty in Table 2.1 (Bilgiç & Konak, 2016).

In architectural education, ideas are mainly presented through drawings. This is an issue that has been extensively covered in the literature and is reflected in the findings of the research (Table 2). It can be said that drawing techniques are, to some extent, a skill that should be acquired by students before undergraduate studies. The need to present ideas through visual communication can be encountered in many areas of life. On the other hand, gaining skills in technical drawing also means advancing spatial thinking skills, which have an important place in competencies in STEM disciplines (Cole et al., 2018). Although the pre-undergraduate visual arts course touches on visual communication to some extent, it is not sufficient. In the context of STEM education, students are expected to be able to convey their design ideas through technical drawings or graphic drawings. It can be easily stated that technical drawing and graphics education should be provided at least at the high school level, including students other than technical high schools. The recommendation to add courses that will improve technical drawing skills to high school programs may be the fifth conclusion that can be drawn from architectural education.

Adapting the Culture of Criticism

Meeting the culture of criticism: Criticism in architectural education is a challenging but essential learning tool for students. In the design studio, students are exposed to criticism from instructors during their presentations. Criticism enables students to develop their critical thinking skills and professional knowledge in architectural education (Hettithanthri & Hansen, 2022; Pasin, 2017; Yılmaz & Ulusoy, 2016; Yurt et al., 2020; Yüksel et al., 2021). In a sense, instructors represent physical realities and cultural values in front of students. Criticism sometimes improves students by breaking their prejudices and has an important place in architectural education, but is a challenging process (Aykaç, 2021; Oh et al., 2013).

In the discussions above, it was mentioned that the instructors represented physical and cultural reality in their table critiques in the architectural design course. From the observation statements in Table 2 and readings of the relevant literature, it can be said that teachers' representations of reality are the essence of architectural education. Field specialization training is mainly provided at the undergraduate (K16) level. In this context, it can be said that the conditions for using the desk critique method in project work are available. Students can be given project topics with a real-life context. Since teachers are field experts, they must have the knowledge and skills to represent real life. Therefore, they can represent the physical and cultural reality of that professional field. However, it is not seen that similar topics are covered in the literature. When it comes to STEM education at the K16 level, the literature mostly investigates disadvantaged representation problems such as gender, skin color, disability, and the reasons for dropping out of school in the first years of undergraduate education (Li et al., 2020). It is known that graduation projects are compulsory courses in engineering departments in our country, even though their credits are not high. However, compulsory graduation papers (project courses) in engineering departments are overshadowed by the success concerns of theoretical courses and are not given as much importance as in the faculty of architecture. As mentioned in the literature section, two dimensions of technical education are mentioned: *Technical rationality* and *reflection in action*. After the 1970s, priority was given to *technical rationality* in engineering education. Thus, in a sense, it can be said that theory is hierarchically superior to practice (Ylirisku & Filz, 2018).

Despite this, graduation papers should be structured based on the design studio approach (criticism culture) in architectural education and implemented as a compulsory course and should be a graduation qualification course with high credits. Supporting this prioritization, Chance et al. (2013) have argued that the design studio approach is "one of the best learning and professional development systems considered" for all of higher education, but also that it is becoming widespread at the K16 level. So, as the sixth inference in the context of architectural education; It can be said that in addition to the paradigm change in theory/practice (technical rationality and reflection in action) that faculty members should experience at the undergraduate level, radical institutional preparations such as assessment and evaluation with the jury system should also be made. For grade levels K12 and below, the fact that teachers do not have industry-related professional expertise limits students' possibilities of determining a project topic, and the teacher can't represent reality on the selected project. Therefore, with the high school level being an exception, the cognitive and psychomotor competencies of students at the K4 and K8 grade levels eliminate the possibility of product-oriented, project-based STEM education. Instead, as discussed above in the Reality in Problem Situation subheading, it seems possible to adapt STEM activities at K8 and K4 grade levels to include physical experiences within the design studio approach, starting with identifying a real problem.

To summarize, at the end of this discussion, six conclusions were drawn in the context of reflecting the knowledge of architectural education into STEM education:

1- In STEM education, students at all grade levels should be given the opportunity to solve the problem on their own from beginning to end. In other words, when faced with an open-ended problem, the student should develop own solution method by trial and error and by learning from his/her mistakes. Although this is not an unknown issue for STEM education, it is recommended to place more emphasis on dealing with uncertainties on the way to solution and to increase the time and program weight.

2- It is very important to provide students with high motivation in tackling open-ended problems. For this purpose, STEM project courses should be converted into graduation qualifications. Provided that motivation is provided, a successful project-based STEM education can be targeted at undergraduate (K16) and high school (K12) grade levels. On the other hand, when students' knowledge and skill levels are taken into account, an approach that places STEM education, which focuses on problem situations, as the basis of programs at secondary school (K8) and primary school (K4) grade levels, may be meaningful.

3- The problem themes of the Architectural Design course focus directly on real life. In STEM education, this corresponds to the principle known as real-life context. However, a standard has not been established in establishing the context in STEM education. In this sense, the concept of authenticity of the problem has been defined in order to emphasize the importance of the real-life context and to set a measure. What is meant by the real problem statement is the sustainability and economic value dimension. Problems of questionable authenticity should be avoided.

4- Although children at the secondary school (K8) and primary school (K4) grade levels will not aim to obtain a concrete product in the context of a real problem, STEM education focused on deepening the problem situation can be provided. However, for these grade levels, children should be able to familiarize themselves with the materials, tools and equipment in the context of the problem by experiencing them firsthand.

5- It can be said that drawing and graphic skills, which have a big place in architectural education, are necessary in almost every aspect of life today. Therefore, in order to provide project narratives in STEM education activities, it is recommended to add courses that will improve technical drawing skills to the programs, including non-technical high schools.

6- In addition to the theory/practice (technical rationality and reflection in action) paradigm change that faculty members need to experience for real success in project courses/final papers in STEM disciplines at the undergraduate level, it is also recommended to make radical institutional transformation preparations such as measurement and evaluation with a jury system.

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