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AN EXAMINATION OF STEAM ENGINEERING DESIGNS IN THE PRE-SCHOOL PERIOD

(Case Study)

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Abstract

STEAM embodies an integrative educational approach that holistically synthesizes Science, Technology, Engineering, Art, and Mathematics. The implementation of STEAM pedagogies within early childhood or pre-school curriculums significantly bolsters children's abilities in design, design thinking, innovation, creative thought, problem-solving, and critical thinking. The primary objective of this study is a comprehensive exploration of preschool-aged children's processes in STEAM design. This study employs a qualitative case-study research design, incorporating a convenience sample of 12 pre-school children from an independent kindergarten overseen by the Provincial Directorate of National Education. A 'STEAM design observation form,' devised by the investigator, and photographs capturing the design process, function as the primary data collection tools. The data analysis process was guided by content analysis methods, leading to the categorization of data into two core themes - design planning and design execution. The results of this study indicate that children are actively involved in STEAM design processes. They formulate and execute age-appropriate designs, efficiently employing engineering design processes in their work. With these findings, this study offers insights and recommendations for practitioners and researchers aiming to cultivate and enhance STEAM design principles within preschool educational settings.

Keywords: STEAM, preschool, design process, engineering, early childhood

1. Introduction

STEAM represents an advanced pedagogical paradigm, amalgamating science, technology, engineering, art, and mathematics, viewed through a comprehensive, interdisciplinary lens. The benefits of STEAM education, which have gained significant recognition and prevalence over the years, extend to holistic child development, notably in realms of problem-solving, design, scientific process abilities, and creative and critical thinking, as corroborated by numerous scholarly investigations (Mercan, 2019; Kavak & Deretarla Gül, 2020; Abanoz & Deniz, 2021).

STEAM methodologies can be efficaciously integrated into both formal and informal educational settings. While the STEAM approach has seen widespread application in traditional classroom environments and extracurricular learning activities, its influence on informal, everyday learning has been the subject of extensive research (Abanoz & Deniz, 2021; Gözüm, 2022; Gözüm, Papadakis, Kalogiannakis, 2022; Mercan, Papadakis, Gözüm, & Kalogiannakis, 2022;Mercan & Kandır, 2022). In the continuum of formal education, spanning early childhood to higher education, STEAM principles find diverse applications. Evidence suggests that early exposure to STEAM engenders a greater interest in the discipline, kindles curiosity, promotes the recognition of STEAM concepts, and even cultivates a predisposition towards STEAM-related professions in the future (Azkın, 2019).

Optimal implementation of STEAM in early childhood education necessitates a hands-on approach, fostering experiential learning. In this context, STEAM engineering design processes play a crucial role in enabling children to identify and define daily life problems, propose potential solutions, experience and refine the solutions. Empirical studies underscore the benefits of STEAM engineering design in enhancing children's problem-solving abilities and in stimulating design-centric, creative, and innovative thinking processes. Accordingly, STEAM engineering design processes entail questioning, imagining, planning, creating, improving, and reflecting (Jackson et al., 2011; DeJarnette, 2018; Mercan, 2019). The present study aims to delve into preschool children's STEAM engineering design processes.

1.1.Theoretical Framework

Within the STEAM design process, children acquire design thinking skills, a process that is inherently curiosity-driven. In this process, children identify a problem related to their subject of interest and develop a design to resolve this issue. Design thinking employs a solution-focused strategy that initiates with an end-goal rather than a problem. As such, the process stimulates a user-centered approach that integrates logic, imagination, intuition, and systemic reasoning (Armitage et al., 2017). Razzouk and Shute (2012) conceptualize design thinking as an analytical and creative process that enables experimentation, modeling and prototyping, feedback reception, and redesign. In this regard, the STEAM educational approach, specifically its engineering design component, robustly underpins design thinking. Existing research suggests that the STEAM education approach fosters design thinking with its interdisciplinary and holistic perspective (Sarıkoç, & Ersoy, 2022).

> "STEM education in learning integrates the ideals of design thinking with the engineering design process. During the design process, individuals learn how to define a problem or need, how to consider available options and constraints, and how to plan, model, test, and iterate solutions, making higher-order thinking skills tangible and visible (Honey & Kanter, 2013)." (as cited in Gürkan, 2022)

Brown's conceptualization of the design thinking process is presented in three distinct stages: Inspiration, Ideation, and Implementation. The preliminary stage, Inspiration, encapsulates the identification and comprehension of a problem or the requirements of the user. Subsequently, the Ideation stage is characterized by the generation of an array of potential solutions to the identified problem. The final stage, Implementation, necessitates the execution of the ideated solutions (Girgin, 2020). The schematic representation of the design thinking process, as per this framework, is delineated in Figure 1.

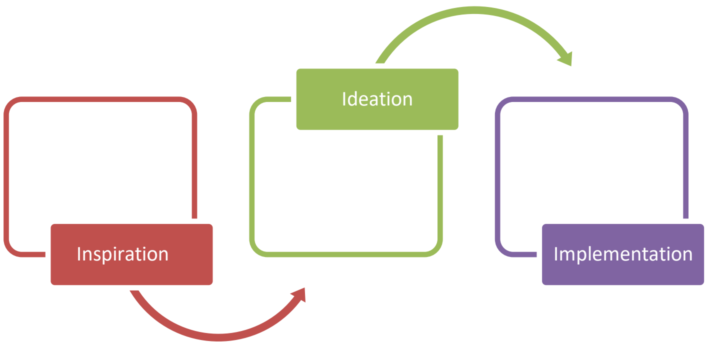

Figure 1. Design thinking process

Design-oriented thinking ought to be the cornerstone of formal education processes, beginning from the preschool years. In the landscape of 21st-century education, design thinking forms the foundational basis for nurturing individuals who are both creative and innovative. Children who can manipulate their circumstances with a solution-oriented mindset simultaneously enrich the dynamic educational process with their capacity for questioning, critiquing, and problem-solving. Given that design thinking encapsulates strategies aiming to enhance product design (Chin et al., 2019; Aydemir & Çetin, 2021), children are afforded the opportunity to engage in creative and innovative thinking within this framework.

Extant literature underscores that innovative thinking is integral to creative and design-based learning environments. To explicate the concept of innovative thinking, it is essential to touch upon the term "innovation." Although often conflated with the terms "novelty" or "invention" in Turkish, the literature suggests that while innovation embodies novelty, it is not wholly reducible to the concept of invention. As posited by Begüm (2022), "Innovation is predicated on scrutinizing existing solutions, it does not signify the 'new' per se, but rather implies the refinement and advancement of the extant, and finding solutions to address need." Thus, the notion of innovation can be construed as an inclusive concept, encompassing creative thinking and entrepreneurship, along with novelty. However, the term "innovation" finds application not solely in the realm of education but extends to various economic, social, and societal fields. Related studies, while delineating the concept of innovation within an educational context, assess innovative and creative practices in relation to this concept (Said, 2017). Within curricular frameworks, innovation represents the ability to engender novelty by developing and implementing unique, distinctive, and fresh ideas that address unsolved problems or meet unfulfilled needs, or by initiating the use of novel methodologies in the context of existing products or services.

While the terms "creative thinking" and "innovative thinking" are frequently used interchangeably or analogously in numerous sources, there exist distinct areas where these two modes of thought diverge.

> "For innovation to take place, there must be a creative process, but not every creative process has to be transformed or converted into a monetary value. Amabile (1997), known for his definition and studies on creativity, states that creativity is the first step towards innovation and innovation is the successful implementation of creative ideas. Creativity is an individual endeavor, while innovation is a team effort. The innovation process starts with a need based on a creative idea (Tanner, 1994). While creativity is a cognitive process, innovation is a social process (Rank et al., 2004)" (as cited in Keleşoğlu & Kalaycı, 2017).

As per Rattcliffe's (2009) framework, the design thinking process can be bifurcated into two distinct domains: the problem domain and the solution domain. This process, being non-linear in nature, further subdivides the problem domain into three phases: understanding, observation, and perspective. Correspondingly, the solution domain is segmented into three stages: ideation, prototyping, and testing (as cited in Girgin, 2020).

Within the STEAM design process, children engage in problem domain activities during the 'ask questions,' 'imagine,' and 'plan' stages, while the solution domain emerges within the 'create,' 'develop,' and 'reflect' stages. Consequently, it can be posited that there exists a notable similarity between Rattcliffe's (2009) design thinking and the STEAM engineering design process (DeJarnette, 2018; Jackson et al, 2011; Mercan, 2019). In both frameworks, a six-stage progression is observed, beginning with the recognition of a problem and culminating in the transformation of a solution into design. The STEAM design process represents a design-oriented, creative, and innovative undertaking. It is design-oriented due to its inception with the recognition of a problem, which evolves into the discovery of a solution and the integration of this solution with design. The process exhibits its creative nature as children within this framework generate new ideas, develop diverse perspectives, and engage in cognitive activity. As an innovative process, it encourages children to collaborate in groups, thus offering social experiences. Furthermore, the solutions they devise contribute to societal improvement.

2. Methodology

This section outlines the research model, study group, data collection, and data analysis procedures employed in the study.

2.1.Research Model

The study was executed employing a case study approach, as part of qualitative research design. A case study can be defined as an intensive study about a person, a group of people or a unit, which is aimed to generalize over several units. A case study has also been described as an intensive, systematic investigation of a single individual, group,community or some other unit in which the researcher examines in-depth data relating to several variables (Heale and Twycross, 2018). Within this context, the STEAM engineering design processes of preschool children were examined.

2.2.Study Group

The study group was selected via the convenience sampling technique and comprised 12 children enrolled in an independent kindergarten affiliated with the Ministry of National Education. All children in the study group were volunteers and aged between 5 to 6 years. In this respect, the study group included an equal number of girls and boys.

2.3.Data Collection

This subsection presents details regarding data collection tools and the process of data collection.

Data Collection Tools

In the study, the "STEAM Design Observation Form," developed by the researchers based on relevant literature (Jackson et al., 2011; DeJarnette, 2018; Mercan, 2019), along with photographs depicting the design process, were employed. Specifically, the STEAM Design Observation Form captures stages related to the STEAM engineering design process ('ask questions,' 'imagine,' 'plan,' 'create,' 'develop,' and 'reflect') (Refer to Figure 2). Photographs of the design process were chosen from a pool of 20 images reflecting various engineering design processes.

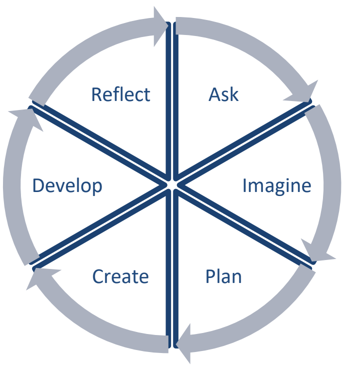

Figure 2. STEAM engineering design process

2.4.Data Collection Procedure

During the data collection process of the study, the researcher engaged with the children in two separate sessions, executing a "STEAM houses project".

The "STEAM houses project" commenced with a discussion about various types of houses and the reasons people choose them, thus sparking the children's curiosity about housing. Subsequently, children were prompted to draw their dream houses and provide verbal descriptions of their drawings. Based on the drawings, the children were encouraged to formulate plans to design their dream homes. The children then chose suitable construction materials such as Lego bricks and blocks for their designs. Upon building their dream houses using these materials, they explained their designs to the researcher, teacher, and peers, refined their designs based on received feedback, and presented their final creations.

During this process, the researcher recorded data using an observation form. For the purpose of confidentiality, each child was assigned a unique identifier, such as C1, C2,...,C12, replacing the children's names during the data collection procedure. Additionally, photographs documenting the design processes were used as corroborative documents.

2.5.Data Analysis

Content analysis was employed to scrutinize the data. Within this context, data were analyzed under the themes of 'design planning and implementation' and 'adaptation.' The 'design planning and implementation' theme was further divided into sub-themes, namely 'ask,' 'imagine,' 'plan,' 'create,' 'develop,' and 'reflect,' while the 'adaptation' theme was concerned with the alignment of planning and implementation processes.

3. Findings

The findings of the study were discussed under two main themes: 'STEAM engineering design planning and implementation,' and 'adaptation.'

3.1.STEAM Engineering Design Planning and Implementation

The STEAM engineering design process commences with children asking questions. The objective here is to stimulate children's innate curiosity and prompt them to recognize potential problem situations.

Ask Questıons

In alignment with this objective, the researcher stimulated the children by posing inquiries about various types of houses. This involved discussing a wide array of house types such as wooden houses, stone houses, tree houses, mobile homes, adobe houses, ice houses, skyscrapers, detached houses, villas, and apartments. Throughout this dialogic process, open-ended questions following the '5W1H' model (Who, What, Where, When, Why, and How) were utilized, crafting a conducive environment that encouraged children to share their ideas and past experiences.

Imagıne

The second phase of the STEAM engineering design process, the Imagination phase, engages the researcher in soliciting children's ideas about their dream homes. The children are invited to manifest their dreams via illustrations. Consequently, the findings derived from the visual representations of children's envisioned abodes are depicted in Figure 3.

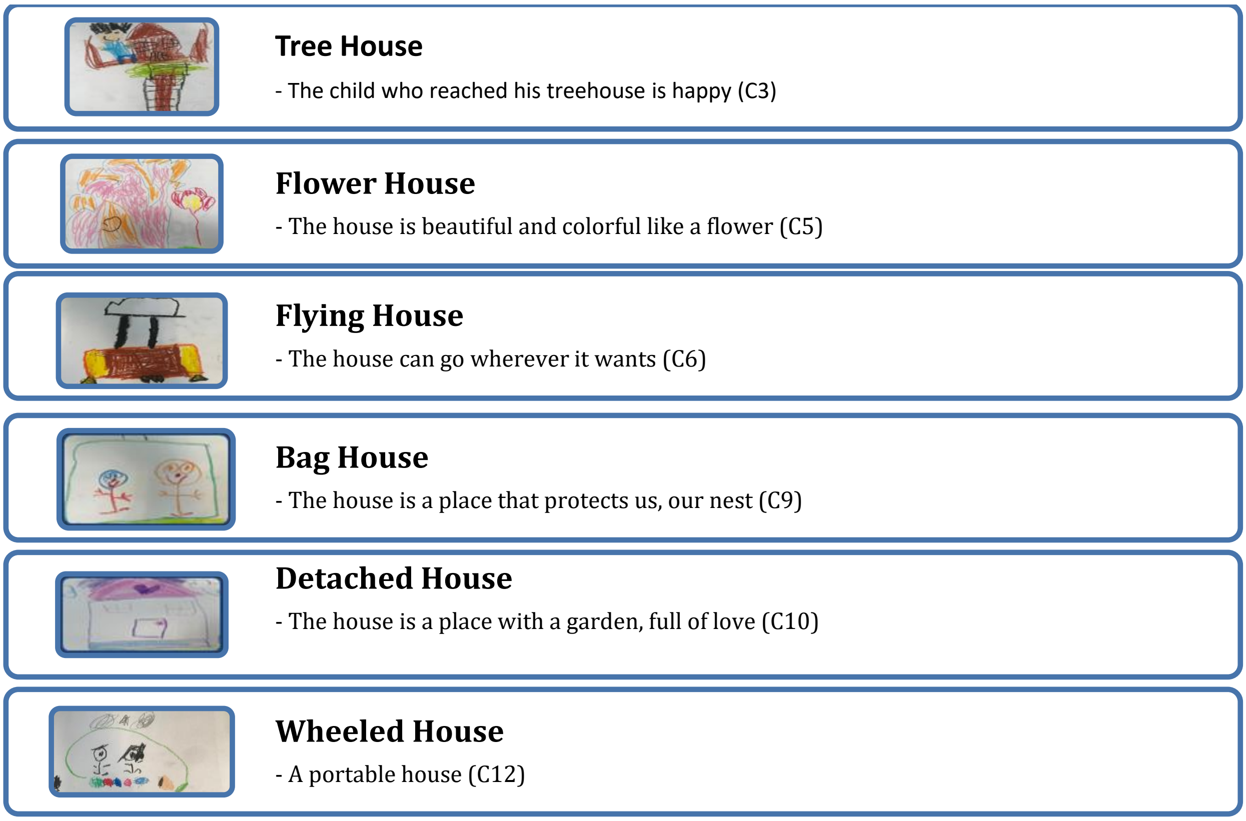

Figure 3. Depictions of Children's Conceptualized Houses

As depicted in Figure 3, the children conceptualized and sketched a variety of dwelling types, including a tree house, a flower house, a flying house, a bag house, a detached house, and a mobile, wheeled house.

Plan

In the planning phase of the STEAM Engineering design process, children were prompted to generate plans for constructing the houses they had envisioned. Questions probing the attributes of the imagined houses were posed, such as "Which material would be the most durable?" "What dimensions should the house possess?" and "Which color would you select?" The children were encouraged to decide upon their preferred building materials via these queries. Choices available to them included Lego bricks, blocks, and various other construction resources.

3.2.STEAM Engineering Design Process Implementation

The implementation phase of the STEAM Engineering Design Process encompasses the stages of creation, development, and reflection.

Create

At this juncture, the children were instructed to actualize their dream houses, which they had previously visualized and planned, into tangible designs. The children chose their preferred mediums from a selection that included blocks, Lego bricks, and other constructive materials, thereby bringing their three-dimensional designs to fruition. Figure 4 provides additional insights regarding the children's architectural creations.

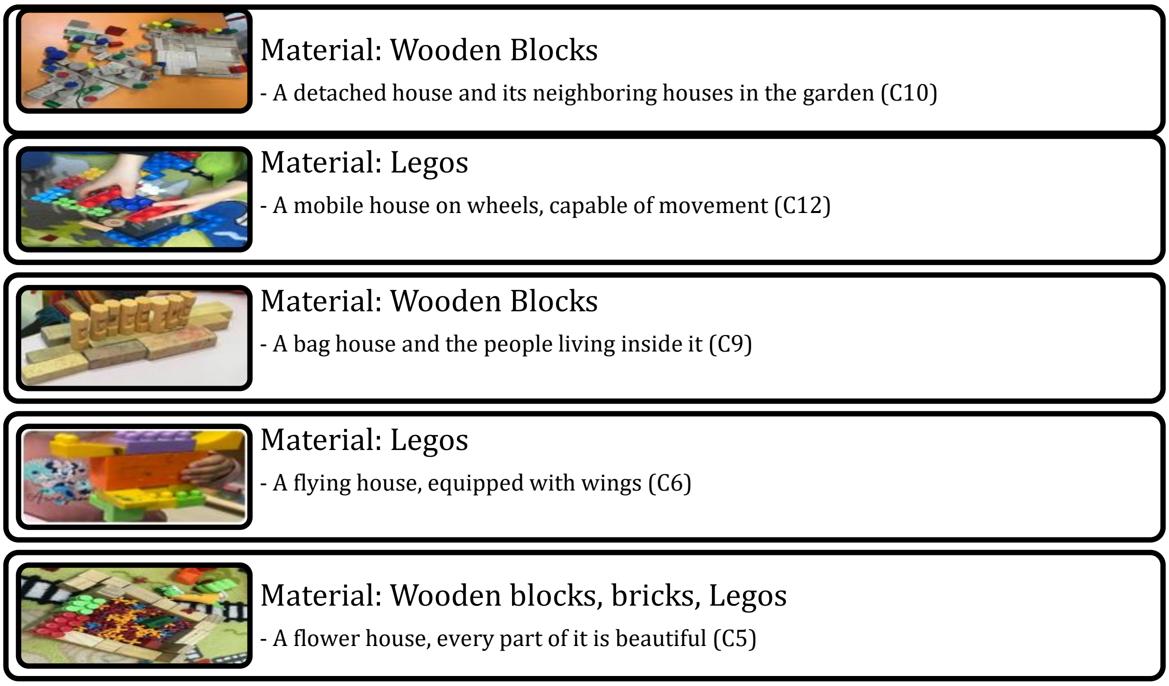

Figure 4. STEAM Engineering Designs

Develop

During the development phase of the STEAM Engineering design process, children were encouraged to critically evaluate their designs, prompted by a set of probing inquiries about the design parameters. Questions such as "Is the house the size you envisaged?", "What modifications could make it taller?", "Does this house reflect the durability you intended?", "How could you enhance the structural integrity of the house?" were utilized to stimulate the children's analytical faculties.

The children were organized into small working groups (comprising 4-5 individuals), thereby establishing an environment conducive to collaborative learning. They were given the autonomy to select their group members, thereby fostering a sense of ownership over their learning process. This format aimed to facilitate effective communication among peers, promote efficient utilization of the feedback mechanism, and empower children to refine their designs based on the received feedback.

Throughout this process, the researchers played a pivotal role in guiding the children. They functioned as facilitators, ensuring a fluid interchange of ideas among the group members, and providing supportive feedback to direct the children's design improvement efforts. The development phase epitomizes the iterative nature of the STEAM Engineering design process. Here, children are not merely creators but active participants in a continuous cycle of design, feedback, and improvement, thereby fostering their critical thinking, collaborative learning, and problem-solving skills.

Reflect

The final phase of the STEAM Engineering design process was dedicated to reflection. In this stage, children were given the opportunity to showcase their designs to their peers, teachers, and researchers. This platform for expression not only allowed them to articulate their thoughts and the creative process behind their designs but also fostered self-confidence and public speaking abilities.

3.3.Adaptation in Steam Engineering Design Process

The STEAM Engineering design process has immense educational potential, enabling children to learn by doing and experiencing. By fostering the ability to recognize, define, and address problems derived from everyday life, the process encourages the development of problem-solving abilities, innovative thinking, and hands-on skills. A significant measure of success in the STEAM Engineering design process is the alignment between what was planned and what was ultimately created. It is in this context that the concept of adaptation becomes

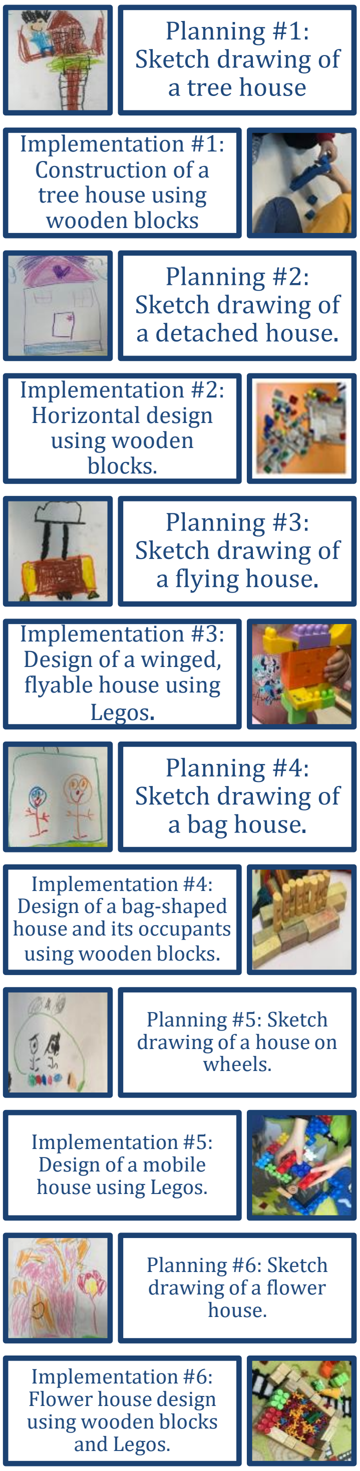

Figure 5. Comparison of the children's original plans and their final implementations

particularly relevant. Adaptation refers to the degree of harmony between the original plans and the actual designs produced by the children. This measure of alignment, or adaptation, offers a useful metric to gauge the effectiveness of the design process. The nature of this adaptation is elucidated in Figure 5.

Upon analysis of Figure 5, it becomes evident that children have been successful in creating the products they conceptualized during the STEAM Engineering design process.

4. Discussion and Conclusions

This research study fostered curiosity in children using open-ended questions posed by researchers. The collected responses provided a canvas for the children to express their ideas through sketches. Subsequently, they were supported in translating these ideas into tangible three-dimensional designs. Throughout the process, children exercised their innovative expression and developed numerous abilities such as group collaboration, problem-solving, and product creation. This exercise embodies the essence of a learner-centered design thinking approach. This method presents a modern perspective on education, endorsing an active learning experience for children. It also encourages them to transform knowledge into practice and remodel existing knowledge for this purpose. This perspective aligns with the constructivist educational philosophy and underscores the dynamism involved in the knowledge acquisition process.

This research aims to explore the experiences of preschool children undergoing the STEAM engineering design process. The children's participation in the "ask, imagine, plan, create, improve, and reflect" stages of the design process was noteworthy. These stages allowed children to demonstrate their ability to inquire, conceptualize, translate dreams into sketches and verbalize them, think about problem-solving techniques, and realize these solutions in the form of three-dimensional designs. The process also included explaining their designs in a cause-effect framework. The study observed children showing cooperation and sharing skills while working in small groups. The "reflect" stage had children sharing their designs with their peers or adults.

In the relevant literature, design thinking encompasses inspiration, ideation, and implementation (Brown, 2008). Design stages include problem domain and solution domain (Rattcliffe, 2009, as cited in Girgin, 2020). The STEAM engineering design process includes stages such as asking questions, imagining, planning, creating, improving, and reflecting (Jackson et al., 2011; DeJarnette, 2018; Mercan, 2019). The exercises in this study facilitated the children to think design-oriented, experience design stages, and apply the STEAM engineering design process.

A review of related literature reveals an abundance of research on the STEAM education approach, encompassing all formal education processes from early childhood to informal education processes (Mercan, 2019; Kavak & Deretarla Gül, 2020; Abanoz & Deniz, 2021; Gözüm, Papadakis, Kalogiannakis, 2022; Mercan, Papadakis, Gözüm, & Kalogiannakis, 2022; Gözüm, 2022). These studies illustrate that the STEAM education approach contributes to children's thinking skills, social skills, and manual skills with its interdisciplinary and holistic perspective. The research on the STEAM engineering design process reveals that children gain hands-on experiences, develop an interest in the field of engineering, acquire design skills, and STEAM concepts and skills (Madenci & Yılmaz, 2019; Mercan & Kandır, 2020).

There's an increased focus on the STEAM approach in early childhood in recent years. However, research on STEAM engineering design processes remains limited (Karakaya & Yılmaz, 2021; Madenci & Yılmaz, 2019). Internationally, research on the STEAM education approach, STEAM engineering design process, and STEAM makerspace has gained momentum in recent years (DeJarnette, 2018; Ozkan, G., & Umdu Topsakal, 2021). While the increase in both national and international studies is promising, considering the importance of early childhood, there is a need for more comprehensive and qualitative research on the subject.

This research study provides valuable insights into children's STEAM engineering design process, thus enriching the literature. The study's findings, such as enhancing children's thinking and social skills, align with the results found in the literature (DeJarnette, 2018; Kavak & Deretarla Gül, 2020; Mercan & Kandır, 2019).

Expanding upon these findings, the following comprehensive recommendations can be proposed:

• Increase Scientific Research on STEAM Engineering Design Process: There is a need to amplify the volume of scientific research specifically focused on the STEAM engineering design process. Detailed studies should be carried out to understand and document the varying impacts of this process on children's cognitive, behavioral, and skill development. This would contribute to creating a stronger evidence base, enabling the development of more effective and engaging STEAM learning modules.

• Prioritize Early Childhood in the STEAM Engineering Design Process: Given the importance of early cognitive development, prioritizing the introduction of STEAM engineering design process in early childhood education should be strongly considered. Early exposure to such interdisciplinary, creative, and problem-solving approaches can cultivate innovative thinking skills, promoting a lifelong enthusiasm for learning.

• Blend In-school and Out-of-school Experiences: To promote a comprehensive learning experience, the STEAM engineering design process should be integrated with both in-school and out-of-school activities. Real-world applications of STEAM principles can greatly enhance a child's understanding and interest. Therefore, field trips, community projects, and practical tasks at home can be useful supplements to classroom activities.

• Emphasize Collaboration Among Schools, Families, and Communities: The promotion of the STEAM engineering design process should not be limited to the school environment. Instead, it should be seen as a collaborative effort among schools, families, and the wider community. Parental and community involvement can enhance the practical and societal relevance of the activities, thereby increasing the children's interest and engagement.

• Encourage Research Linking STEAM and Innovative Thinking: Further studies should explore the correlation between the STEAM engineering design process and the development of innovative and creative thinking in children. Aspects like problem-solving abilities, creativity, and design thinking should be the focal points of this research. This can provide deeper insights into how STEAM education can best be utilized to foster an innovative mindset in children.

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