International Journal of Social Science and Human Research

ISSN (print): 2644-0679, ISSN (online): 2644-0695

Volume 08, Issue 12 December 2025

DOI: 10.47191/ijsshr/v8-i12-96, Impact factor- 8.007

Page No: 10006-10011

STE(A)M-Based Open Play Toys Hands-On Learning Intervention in Jakarta's Dense Urban Spaces

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ABSTRACT: The limited availability of educational and stimulating physical play spaces in household environments and dense urban communities in Indonesia presents obstacles to optimizing hands-on learning for preschool and elementary school children (5–8 years old). This problem is exacerbated by the high level of parental concern about gadget dependence that triggers a decline in children's motor and logic skills. This study aims to design an STE(A)M-based Open Play Toy System as a non-digital intervention product solution that effectively addresses these space and behavioral issues. The design concept emphasizes modularity (components can be transformed into various forms and functions) and portability, which intelligently 'creates' functional play spaces in limited land. This toy focuses on optimizing hands-on learning through the integration of STE(A)M (Science, Technology, Engineering, Arts, Mathematics) principles, in line with children's interests in construction and arts/crafts. The design methodology is based on the ergonomics of elementary school children and an in-depth analysis of user needs in Indonesia regarding space efficiency and resistance to boredom. The resulting design is an intuitive educational toy that is flexible for indoor and outdoor use, and offers a cognitively challenging play environment. This product is expected to become a tangible intervention tool, providing quality play experiences essential for the growth and development of Indonesian children.

KEYWORDS : Educational design, interactive, modularity, STEAM, urban society.

I. INTRODUCTION

Open Play is defined as a play method characterized by the absence of rigid rules or predetermined outcomes. The essence of this concept is to give children the freedom to interact with play materials in a variety of ways, thus supporting flexible and divergent thinking (MECK Pre-K, 2023). The primary goal of open play is to foster creativity, spark creativity, and hone problem-solving skills through independent exploration, which fundamentally supports children's cognitive and social development. This flexible play method has been used for generations and has proven effective. Classic examples of highly popular and sought-after open play materials include building blocks (such as Legos or wooden blocks), which allow children to design, disassemble, and assemble an infinite number of objects.

Various methods have been attempted to address device dependence in elementary and preschool children, including screen time timer features on modern devices. However, these software interventions do not address the root of the problem: the lack of space and engaging physical activities as alternatives to devices. Indonesian children, especially in dense urban environments, increasingly lack access to public play facilities that support their cognitive and motor development. In fact, these cognitive issues are exacerbated by the chronic spatial constraints families face. In high-density residential areas, green open space and suitable play areas are often very limited, forcing children to play in narrow alleys or, more commonly, resort to devices due to the lack of engaging alternatives in their immediate environment. This situation creates idle time after school that needs to be filled with meaningful activities. Research conducted by Domoff et al. (2020) shows that excessive screen exposure can negatively impact self-regulation, lead to sleep disturbances, and diminish social skills. Meanwhile, active outdoor play can contribute to improved social skills, problem-solving, and gross motor development (Lee et al., 2023).

STE(A)M is an acronym representing four disciplines: Science, Technology, Engineering, and Mathematics. The term STEM was first introduced in 2001, initiated by Judith Ramaley, a biologist who at the time served as a science administrator at the National Science Foundation (NSF) in the United States (Sanders, 2009). STEM learning is a conceptual approach that combines and integrates academic methods with real-world lessons. The goal is to encourage students to think critically and develop their problem-solving skills. Mastery of STEM methods is expected to make students more competitive in the modern economy. Another term, STE(A)M, is a movement that supports the integration of Art and Design into the school curriculum, recognizing the important role of creativity and aesthetics in critical thinking and problem-solving processes. STE(A)M methods encompass fine arts, music,

history, psychology, philosophy, aesthetics, ergonomics, and physical activities such as sports and dance, all of which contribute to understanding and expression.

The subjects of this study were categorized into two groups, target users and key informants. The primary target users were elementary and preschool-aged children, who are vulnerable to device addiction and in need of STE(A)M stimulation. The key informants in primary data collection (Google Form survey) were parents/guardians of children. The involvement of these key informants was crucial for validating the problem, testing the open play concept, and determining the ergonomic parameters and portability of the toy for intuitive use by the community.

Therefore, an adaptive and portable product design solution was needed, namely the STE(A)M-Based Modular Open Play Toy System. This design concept aims to make this toy an educational game for Indonesian children, while also being an effective general game to overcome gadget dependency. Through its modular and portable nature, this toy intelligently 'creates' functional play space in limited available space (whether in the indoor space of a small urban household or in the corner of a RPTRA (Regional Medium Enterprises) or Community Hall) quickly and efficiently. By focusing on modular physical toys, this design intervention serves as a permanent asset that offers a structured and engaging hands-on learning alternative, optimally supporting the development of creativity and growth in Indonesian children. The setting of this research is the dense urban environment in the Greater Jakarta area, with a focus on two main areas with limitations.

II. METHOD

This research adopts a qualitative method approach as a means to investigate and deeply understand the meanings interpreted by individuals or groups regarding a social or humanitarian issue (Creswell, 2019). Within the framework of this product design, the qualitative approach aims to comprehensively analyze the complex phenomenon of children's gadget dependence and limited play areas, while simultaneously exploring the real needs of users that will form the basis for supporting the design. Therefore, the primary goal of qualitative methods is to expose socially constructed realities through in-depth data collection, including direct observation in natural settings, detailed interviews, and document analysis to create a concise, comprehensive, and structured description of the phenomenon under study (Creswell, 2018).

Data collection in this research was conducted using two primary, complementary methods. First, a literature study was conducted by collecting, sorting, and reviewing published literature and scientific journals to build a strong theoretical foundation, analyze children's behavioral issues (gadget dependence), and seek STE(A)M-based design solutions. Second, a survey was conducted through the distribution of a digital instrument in the form of a Google Form. This survey is aimed at the main target participants, namely parents, guardians of children, and community educator cadres, with the specific aim of obtaining empirical data regarding children's playing habits, preferences for types of open play games, and the functional needs of toys in limited environments, which will be analyzed to determine optimal product design parameters.

III. RESULTS AND DISCUSSION

3.1. Concept of Early Childhood and Developmental Issues

This study aims to lay the foundation for understanding the fundamental characteristics of preschool (3-5 years) and elementary school-aged children, namely the 6-10 year age group, which is the main target group of this design. This age coincides with the concrete operational stage in cognitive development, where children begin to think logically, systematically, and are able to understand the concepts of science, technology, and mathematics through hands-on activities (Piaget, 1964). At this stage, the development of cognitive skills, particularly logical thinking, information processing, and problem-solving, is vital and dependent on the quality of structured stimuli. Recent literature emphasizes that the development of adequate attention span is not achieved through passive stimulation, but rather through physical interaction and in-depth engagement with real objects that require gradual exploration. These findings indicate that children, particularly at this age, are not solely attracted to novel events but also preferentially explore activities from which they can learn the most. Furthermore, individual differences in performance are closely related to children's engagement with the task. Children who perform better were also engaged in activities that offered high learning potential, while those who performed worse were more focused on familiar, less challenging activities (Poli et al., 2024). These insights extend existing knowledge by confirming that encouraging deep, hands-on exploration that facilitates learning is vital for sustained attention and cognitive development.

3.2. The Phenomenon of Device Dependence

The issue of device dependency in early childhood has become a crucial concern since the beginning of the 21st century, along with the increasing accessibility of digital devices and their penetration into the family sphere. Based on a literature review (Lakicevic et al., 2025), this phenomenon is defined by excessive screen time in preschool through elementary school children. The analysis shows that app design characteristics, which encourage passive and fast-paced content consumption, are significantly correlated with the emergence of impulsive behavior, decreased sleep quality, and emotional regulation problems in children. Thus,

the literature confirms that uncontrolled device use not only impacts cognitive aspects but also threatens the socio-emotional and physical development of early childhood, making it an urgent issue requiring intervention through alternative design.

3.3. STEAM Method

The educational approach underpinning this design is STE(A)M, an acronym for Science, Technology, Engineering, Arts, and Mathematics. STE(A)M is an extension of the foundational STEM framework, primarily differentiated by the inclusion of the Arts component , which was initiated by the Rhode Island School of Design (RISD) to foster innovation that is both functional and aesthetic (Sanders, 2012). By integrating Arts (including design, visual, and humanities), the STE(A)M approach trains children to use both the right and left brain simultaneously, combining technical analysis with creative and innovative thinking. For this reason, this modular toy utilizes the STE(A)M framework, positioning the product design as a solution to both technical and social issues. STE(A)M-based games are not inherently complicated or expensive, nor do they require specialized technicians or teachers; the limitation lies in the child's cognitive development level, where complex concepts are presented through engaging hands-on activities (Kao et al., 2025). Furthermore, the transition from early childhood education to Primary School is an important developmental milestone, which requires effective approaches, such as fun learning, to ensure children adapt positively to the new environment and gain constructive learning experiences. This fun learning approach is central to building a positive foundation for a child's educational journey, promoting engagement and preparing them for subsequent educational changes (El Khuluqo, 2021).

3.4. Survey Results Design Needs and Urgency of Intervention

The survey was conducted with 72 respondents (80.6% parents/guardians), with the majority focusing on children aged 5–8 years (47.2%). The survey was conducted online via the Google Form platform, distributed to parenting communities on social media (particularly Instagram) and relevant personal networks. This convenience sampling method was chosen to quickly reach the target group of parents, guardians, or relatives with young children. The specific objectives of this survey were to identify children's interests and preferences regarding current types of open play games and to accurately determine the age range of product users as initial validation for determining the dimensions, complexity level, and ergonomic parameters for open-play toy product design.

A. The Urgency of Space Limitations and Gadget Concerns

Analysis of living conditions shows that 31.9% of respondents live in urban areas with limited space (apartments, small houses). This data reinforces the need for modular and portable product design solutions to optimize play space. Concern about device use is very high, with 47.2% of respondents choosing a scale of 5 (Very Concerned) and 34.7% choosing a scale of 4 (Concerned). Cumulatively, 81.9% of respondents indicated a significant level of concern (scales 4 and 5). Although the duration of device use is mostly less than one hour per day (93.0%), this finding underscores the strong urgency for parents to find effective non-digital intervention solutions.

B. Children's Preferences and Design Challenges

Children's most preferred physical play activities are Arts & Crafts (26.4%) and Construction/Building (25%). Both of these interests are relevant to the STE(A)M framework because they combine creativity (Arts) with spatial logic (Engineering). Children's spontaneous creative preferences are also dominated by Abstract Forms/Art Installations (26.4%), Tall Structures/Playhouses (22.2%), and Vehicles (22.2%). This data suggests that designs must be flexible to support both artistic exploration (preschool) and structural engineering logic (elementary school age).

The main challenges parents face in providing sustainable hands-on learning activities are:

1. Children Get Bored Quickly (30.6%).
2. Educational Toys Are Expensive (27.8%).
3. Limited Storage Space (25%).

Survey data identified children's creative preferences during open play, which served as an important guide in determining the functionality of modular toys. The majority of respondents (26.4%) stated that their children tended to create abstract forms or art installations, demonstrating a strong drive for free-form creativity (Arts) and visual exploration. This interest was followed evenly by children's desire to create tall structures or playhouses (22.2%) and vehicles (cars, scooters, boats, etc.) (22.2%). Meanwhile, making furniture (tables, chairs) was chosen by 20.8%, and simple scientific models (such as bridges) by 16.7% of respondents.

Age and Design Analysis Based on Creation Preferences

1. Preschool Age (3–5 years): This age group tends to focus on more intuitive outcomes, so abstract works/art installations and role-playing through furniture building will be dominant. Toys should facilitate quick assembly and do not need to be structurally stable.
2. Elementary School Age (6–12 years): This group focuses more on defined goals. They will more often create tall structures/playhouses and vehicles that require an understanding of simple engineering and mathematics principles. The peak interest in simple scientific models (16.7%) also indicates that structural and mechanical challenges become more appealing in elementary school.

In general, building vehicles is often associated with boys' interests due to the mechanics and movement aspects (Engineering and Technology), while building furniture (tables, chairs, etc.) (20.8%) is more likely to be of interest to girls due to its association with role-playing and domestic spatial planning (Arts and Role-play). Interest in activities requiring more advanced physical logic and calculations, such as building simple scientific devices (e.g., bridges or simple mechanisms), was 16.7%, suggesting that these elements should be included as advanced challenges for elementary school-aged children (8–12 years). These data suggest that modular toy designs should be flexible to support artistic exploration (preschool), gender-specific construction (vehicles and furniture), and scientific logic (elementary school). These findings directly validate the importance of modularity and portability in design to enhance play longevity and space efficiency.

C. Existing Product Analysis and Design Specifications

Existing open play variants can be analyzed to identify various experience-based open-play game systems and mechanisms that are not commonly available in the Indonesian market. This analysis is useful for understanding how some imported toys use specific material systems, interactions, or themes, for example, complex magnetic modularity systems, the use of unique and rare natural materials (such as silicone foam or recycled wood fiber), or the integration of sensor-based light and sound elements in building blocks or loose parts games. These can serve as references for the development of innovative local products and enrich the selection of open-ended toys in Indonesia.

A comparative analysis of existing open play products (such as Smarin, Modu, and Interslot) shows variations in system, size, and motor focus :

No	Product Brand	Existing Product Analysis		
		System	**Pros**	**Cons**
1	Smarin 	Large Scale Play (Build and Play Space)	Easy to store and compact. Increase creativity in creating space.	Storage requires a dedicated space due to its large size. Children can become tired of reassembling it.
2	Modu 	Medium scale build and play modular (Foam material)	Supports gross motor skills, balance, and sensory aspects.	Limited durability (prone to tearing), difficult to clean because it absorbs dirt.
3	Interslot 	Small Construction System (Connector Mechanism)	Train fine motor skills and spatial creativity.	Does not support gross motor skills. Risk of component loss is very high.

The conclusion of this analysis is that the proposed product design should utilize medium-sized components (large enough for gross motor skills, but allowing for detailed structures for elementary school children). Most importantly, the product should have a highly efficient and compact storage solution (able to be disassembled and stored vertically), to address space constraints in urban domestic environments, while also providing resistance to wear and tear through maximum modularity.

CONCLUSIONS

Based on all findings, there is a high urgency to design a modular and portable STE(A)M-based *open play* system as a *hands-on learning* intervention. This urgency is driven by the high level of parental concern (81.9% concerned/very concerned) regarding gadget dependence in children, particularly in the 5 to 8 age group. The design solution must address key urban challenges: limited play space and the problem of children quickly getting bored (30.6%). Therefore, the toy must be designed to be modular and portable to 'create' functional play spaces in narrow domestic areas, and feature rich *open play* elements to increase *play longevity*. This approach is essential as the goal is to create a space of creativity, visualization, and connection, moving beyond rigid classroom lessons and the search for a non-class environment. (Ghasemi et al., 2021) The resulting modular space must have the flexibility and capacity to host different educational practices and objectives, recognizing that leading, shaping, and managing an effective learning process is more than simply distributing information. The game's inherent steps communication, exploration, visualization,

and creation serve as a meaningful learning tool that can strengthen the quality of significant targets in the design of effective learning environments

ACKNOWLEDGMENT

The authors wish to express their deepest gratitude for the support received during the completion of this research. This work was made possible through financial and facility support from Universitas Trisakti, Jakarta. Specifically, the authors gratefully acknowledge the Faculty of Art and Design and the Product Design Study Program for providing essential institutional support and resources, including technical facilities and laboratory access. Special appreciation is also extended to the parents, children, and community leaders in Jabodetabek Region who participated in the survey and provided critical data on play habits and space constraints, which directly informed the design solution.

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