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Development of a STEAM Based Science Busy Book to Enhance Early Childhood Cognitive Development

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Abstract: This study aims to develop a STEAM (Science, Technology, Engineering, Arts, and Mathematics)-based Science Busy Book as an innovative learning medium for early childhood education. The research employed a Research and Development (R&D) method using the ADDIE model, comprising the stages of analysis, design, development, implementation, and evaluation. The research instruments included validation sheets, observation checklists, questionnaires, and simple cognitive tests, which were analyzed using quantitative techniques (mean scores and percentages) and qualitative procedures involving data reduction, data display, and conclusion drawing. The results showed that the Busy Book was effective in enhancing children's engagement and cognitive development. The integration of science, technology, engineering, arts, and mathematics enabled children to participate in exploration, simple experiments, and creative activities. Teachers reported that the medium facilitated instruction and made abstract concepts more accessible. In conclusion, the STEAM-based Science Busy Book is feasible, valid, and effective as an early childhood learning medium, supporting the development of scientific literacy in an interactive and meaningful way.

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Introduction

The background of this study originates from findings on the low level of scientific literacy in early childhood (Sumarno et al., 2021; Wibowo, 2021). The level of early childhood scientific literacy is influenced by teachers' understanding of scientific literacy (Shofiyah, 2022). The 2022 Programme for International Student Assessment (PISA) results showed that Indonesia's scientific literacy score ranked 67th out of 79 countries. Although this score indicated some improvement, it remained low due to learning loss as a consequence of distance learning implementation during the COVID-19 pandemic in Indonesia (Kemendikbudristek, 2022; Yusmar & Fadilah, 2023). Learning loss in early childhood scientific literacy can lead to missed opportunities for developing foundational understandings of natural phenomena (Anggraeni, 2022), reduced curiosity, and fewer chances to practice critical and analytical thinking skills that are essential to comprehensively understand their surrounding world (Siswono, 2017). This condition may inhibit their scientific abilities and affect their long-term interest in science (Palenewen et al., 2023).

Early childhood education is a crucial foundation for children's cognitive, social, and emotional development. At this stage, children begin to build thinking skills, problem solving abilities, and basic concepts in science, technology, engineering, arts, and mathematics (STEAM) (Wahyuni & Putri, 2022). However, science learning in early childhood often faces

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challenges, such as the lack of interactive learning media (Hartatik, 2022; Dewi, 2022; Syukri, 2022; Rupnidah, 2022; Hidayati, 2020). For this reason, innovation in learning is required to stimulate children's interest and active participation, one of which is through attractive educational media (Arsyad, 2023; Imaduddin et al., 2021; Rahmawati & Yuliani, 2021).

In response to this phenomenon, researchers propose the use of learning media that can enhance children's cognitive skills through engaging and enjoyable activities, such as busy books. By integrating STEAM concepts into science busy books, children can learn through exploration, experimentation, and realworld experiences. The STEAM approach not only helps children understand scientific concepts more concretely but also develops creativity, critical thinking, and problem-solving skills from an early age (Annisa et al., 2023; Nurhayati et al., 2020; Prasetyo & Wulandari, 2019; Lestari & Hidayat, 2022; Aprita & Kurniah, 2021).

Scientific literacy is a crucial component of early childhood development, forming the foundation for critical thinking, analytical skills, and basic understanding of natural phenomena. However, scientific literacy among Indonesian children remains low. PISA 2022 results place Indonesia at 67 out of 79 countries in scientific literacy (OECD, 2023), a condition further worsened by learning loss resulting from the COVID-19 pandemic (Yusmar & Fadilah, 2023; Suyanto, 2022). These findings indicate that early childhood science learning experiences have yet to optimally support children's developmental needs, particularly in terms of instructional methods and learning media (Shofiyah, 2022).

Early childhood education in Indonesia still predominantly uses picture books and worksheets, which tend to be one directional and lack exploratory engagement (Ismail & Elias, 2020). Although digital media such as videos and augmented reality applications offer improved visualization, they often reduce hands on exploration and fine motor engagement both essential for early childhood scientific learning (Akçayır & Akçayır, 2019; Han & Bhattacharya, 2022). Thus, there is an urgent need for learning media that are interactive, multisensory, manipulative, and capable of stimulating scientific exploration.

Busy books present an appealing alternative because they combine object manipulation, bright visuals, and problem-solving activities. Prior studies show that busy books enhance children's focus, memory, and engagement (Wijayanti & Wulandari, 2021; Rahmawati & Yuliani, 2021). However, most busy books currently used in early childhood settings feature general thematic activities and have not integrated STEAM concepts in a structured manner. Integrating STEAM into early childhood learning is essential because it promotes creativity, problem solving, interdisciplinary thinking, and scientific inquiry (Chen & Wang, 2021; Kaya & Yilmaz, 2022).

Based on the preliminary study, this research is supported by several previous studies, as follows. Previous studies collectively highlight the urgency and relevance of developing interactive and STEAM based learning media to enhance early childhood scientific literacy. Rahmawati and Yuliani (2021) reported that busy books can increase children's learning interest and support their understanding of basic scientific concepts through interactive educational play. This finding is reinforced by Nurhayati et al. (2020), who demonstrated that integrating the STEAM approach into learning media effectively fosters children's critical thinking and creativity, particularly when engaging with science related content. In addition, Prasetyo and Wulandari (2019) revealed that busy books designed attractively and grounded in exploratory activities significantly improve children's memory, concentration, and problem-solving skills. Consistent with these results, Lestari and Hidayat (2022) found that STEAM based learning media offer more enjoyable and meaningful learning experiences,

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thereby contributing positively to children's cognitive development. Collectively, these studies underscore that combining manipulative media such as busy books with the STEAM framework holds strong potential for supporting early childhood scientific literacy and cognitive growth.

The urgency of this study includes Improving the quality of science learning in early childhood education (ECE), Supporting the cognitive development of young children and Serving as a reference for the development of innovative learning media. The purpose of this study is to develop a STEAM based science busy book that aligns with the characteristics and cognitive developmental needs of early childhood, and to evaluate its effectiveness in supporting the cognitive development of young children. The gap in the literature lies in the absence of a learning medium that systematically integrates STEAM components into a science specific busy book for early childhood education. The novelty of this study lies in its comprehensive integration of manipulative activities, simple experimentation, and STEAM based learning components within a single structured medium.

Research Method

This research employed the Research and Development (R&D) method using the ADDIE development model, which consists of Analysis, Design, Development, Implementation, and Evaluation. The stages that have been carried out are the Analysis and Design phases (Lee, H., & Park, S, 2020). The Analysis stage in the ADDIE model was conducted to identify user needs, learning objectives, and potential challenges that may arise. Meanwhile, the Design stage aimed to plan the instructional solutions to be developed. After completing the Analysis and Design stages, the next step is the Development phase, in which the learning content and the STEAM Based Science Busy Book will be created based on the previously designed plans. The Implementation phase will then focus on testing and applying the developed media in early childhood learning settings to evaluate its practicality and usability. Finally, the Evaluation phase will be carried out to assess the effectiveness of the product in improving children's cognitive development, as well as to provide feedback for further refinement.

The study was conducted at TK Labschool IKIP PGRI Jember during the second semester of the 2025 academic year, involving 25 children aged 5-6 years, three early childhood teachers, and three expert validators consisting of two early childhood education lecturers and one instructional media specialist. The instruments used in this research included observation sheets to assess children's engagement, attention, exploration, and interaction; an expert validation questionnaire using a 1-5 Likert scale covering content validity, design, language, and STEAM integration; teacher and child response questionnaires measuring usability, visual appeal, learning relevance, and cognitive benefits; cognitive performance tests assessing observation, classification, and cause and effect reasoning; and documentation in the form of photos and videos taken during the implementation process. Data were collected through structured observations, expert validation, performance tests, teacher interviews, questionnaires, and documentation.

The data analysis employed both quantitative and qualitative approaches. Quantitative analysis used descriptive statistical techniques, including mean scores and percentage calculations, to assess expert validation results, user responses, and children's cognitive performance (Martin & Sun, 2022). Meanwhile, qualitative analysis followed the stages proposed by Miles and Huberman data reduction, data display, and conclusion drawing/verification to systematically interpret observational and interview data (Miles & Huberman, 1994). To support the interpretation of quantitative outcomes, predetermined

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assessment criteria were applied, in which scores of 80% or higher were categorized as Very Good, while scores between 70% and 79% were classified as Good (Moral, Insong, & Santos, 2023).

Result and Discussion

Analysis

The analysis phase of this research was conducted to identify the specific learning needs in early childhood science education at TK Labschool IKIP PGRI Jember. Classroom observations indicated that the majority of children showed limited interest in participating in science learning activities, which were still dominated by conventional methods such as lectures and simple teacher explanations. The data revealed that approximately 72% of the children demonstrated low levels of enthusiasm, as reflected in limited active participation, a tendency to become easily disengaged, and difficulties in completing activities. These findings are consistent with previous studies which highlight that young children require interactive learning media to sustain their focus and motivation in the learning process (Sari & Putri, 2022).

In addition to classroom observations, interviews were conducted with three early childhood education teachers at TK Labschool. The interviews revealed that teachers faced challenges in presenting science content in ways that were engaging and easily comprehensible for children. Teachers reported that the available learning media were mostly limited to illustrated books and worksheets, which were insufficient to optimally stimulate children's engagement. They emphasized the importance of concrete, colorful, and exploration-based learning media that could encourage children's active participation. This aligns with scholarly perspectives that emphasize how innovative media can significantly improve the quality of science learning in early childhood education (Yuliani & Hartati, 2021; Ashadi & Hartawan, 2022).

To strengthen the analysis findings, a review of the daily lesson plan documents (RPPH) was also conducted. The review revealed that science content was already included in the instructional planning; however, the teaching strategies and media employed had not yet supported a STEAM based learning approach. Based on these findings, it can be concluded that there is an urgent need to develop innovative learning media in the form of a STEAM Based Science Busy Book. Such media are expected to address the low levels of children's interest while simultaneously fostering cognitive development through enjoyable, meaningful, and developmentally appropriate activities (Rahmawati, 2023; Chen & Wang, 2021).

Design

The design phase of this study focused on developing a STEAMbased Science Busy Book tailored to the learning needs of early childhood students at TK Labschool IKIP PGRI Jember. At this stage, the researchers created an initial draft in the form of storyboards and content that incorporated simple science themes, such as the introduction of animals and plants, recognition of fruits and vegetables, and the concept of colors. The Busy Book was designed to be interactive, visually appealing with bright colors, and activity oriented, engaging children in fine motor tasks such as lifting flaps, sticking objects, and sliding components. This approach aligns with the perspective that visually engaging instructional media can enhance children's attention and motivation in the learning process (Yuliani & Hartati, 2021).

The design also integrated the STEAM approach (Science, Technology, Engineering, Arts, and Mathematics). For example, in the theme of changes in the states of water, children

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were invited to match pictures of ice, water, and steam, enabling them to learn through concrete visual representations. Artistic integration was realized through coloring and drawing activities, while elements of technology and engineering were reflected in simple mechanical play embedded within the Busy Book. This design aimed to ensure that children not only understood science concepts theoretically but could also connect them with creativity and problem-solving skills. Such integration corresponds with prior research suggesting that STEAM based learning media can strengthen critical and creative thinking abilities in early childhood education (Chen & Wang, 2021; Nugraha & Lestari, 2020).

In addition, the design stage included preliminary validation through a focus group discussion (FGD) with early childhood teachers at TK Labschool. Teachers were invited to provide input regarding the content, layout, and developmental appropriateness of the media. The FGD results indicated that each page of the Busy Book should not only present a single science concept but also include thought-provoking questions, such as "What happens if ice is left outside the refrigerator?". These suggestions were adopted to refine the design of the Busy Book. Through this stage, the researchers ensured that the developed media was not only theoretically sound but also contextually relevant to classroom practices (Rahmawati, 2023; Sari & Putri, 2022)

Development

The development phase represents the stage in which the STEAM-based Science Busy Book, previously designed in the earlier phase, was transformed into a tangible prototype. The Busy Book was produced using child-friendly and safe materials such as flannel fabric, stickers, and Velcro. Each page contained activities emphasizing simple science concepts, including shape matching, sequencing the growth process of plants, and categorizing fruits. The visual design employed contrasting colors and simple illustrations to ensure accessibility and ease of understanding for young learners. This aligns with the perspective that early childhood learning media should prioritize safety, aesthetics, and ease of manipulation (Huang & Chou, 2022).

During this phase, expert validation was also conducted, involving two early childhood education (ECE) lecturers and one instructional media specialist. They were asked to evaluate the feasibility of the content, the appropriateness of the design for young children, and the integration of the STEAM approach. The validation results indicated that the prototype was deemed "suitable for use," with only minor revisions required, such as adding simple instructions for teachers or parents regarding the use of the media. Product validation in development research is essential to ensure that the resulting instructional media is both relevant and of high quality before proceeding to limited trials (Sugiyono, 2019; Rahmawati, 2023).

Revisions were made based on the experts' feedback, including the addition of guiding questions on each page, strengthening the integration of mathematical elements through counting activities, and enlarging the font size to make it more child friendly. Following these revisions, the final prototype of the STEAM based Science Busy Book was ready for classroom implementation. This process highlights the crucial role of the development phase in bridging theoretical design into a practical instructional product that actively and enjoyably enhances children's learning experiences (Sari & Putri, 2022; Yuliani & Hartati, 2021).

The initial prototype of the STEAM based Science Busy Book was validated by three experts: (1) two lecturers specializing in Early Childhood Education, and (2) one instructional media expert. The validation assessed the feasibility of the content, visual presentation,

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language clarity, and the coherence of STEAM integration. A Likert scale (1-5) was employed, where a score of 1 indicated "very poor" and a score of 5 indicated "Very Good".

Table 1. Expert Validation Results of the STEAM Based Science Busy Book

Validated Aspects	Mean Score (1-5)	Criteria
Content Validity	4,6	Very Good
Visual Design	4,4	Very Good
Language (Instructions & Texts)	4,2	Good
Integration of STEAM Concepts	4,5	Very Good
Total Mean Score	4,43	Very Good

The validation results indicated that the STEAM based science busy book achieved an average score of 4.43, which falls under the "Very Good" category. The validators provided several suggestions, including: (1) Adding simple instructions to help teachers or parents guide children more effectively when using the busy book. (2) Enlarging the font size to make it more child-friendly for early childhood learners. (3) Providing example prompting questions in each activity to stimulate children's critical thinking skills.

After minor revisions were made based on the validators' feedback, the busy book was declared feasible for classroom implementation. This expert validation process aligns with Sugiyono's (2019) view that validation is a crucial stage in development research to ensure that the product is consistent with user needs and learning objectives. Following the expert validation and minor revisions, the STEAM based science busy book was implemented on a limited scale at TK Labschool IKIP PGRI Jember, involving 25 children aged 5-6 years. This limited trial aimed to examine both the children's and teachers' responses, as well as to assess the initial effectiveness of the media in enhancing children's engagement and cognitive skills.

Table 2. Teachers' and Children's Responses to the Science Busy Book

Validated Aspects	Mean Score (1-5)	Criteria
Children's Engagement in Learning Activities	4,5	Very Good
Teachers' Perceived Ease of Use	4,3	Very Good
Perceived Visual Attractiveness of the Busy Book	4,6	Very Good
Relevance to Learning Objectives	4,4	Very Good
Total Mean Score	**4,45**	Very Good

The trial results revealed that children were highly enthusiastic in using the science-based STEAM busy book. They actively asked questions, attempted to solve problems, and demonstrated strong curiosity when engaging in the activities. For instance, they connected color concepts with light phenomena, arranged patterns, and conducted simple experiments. Teachers also highlighted that the media facilitated the delivery of science concepts in a more concrete and child friendly manner. Some teachers suggested diversifying the activities and adding simple reflection sheets to help evaluate children's comprehension. These findings align with Nisa and Kurniawati (2022), who emphasized that interactive activity-based learning media enhance children's engagement and reinforce their understanding of basic science concepts.

The limited trial involving 25 early childhood learners at TK Labschool IKIP PGRI Jember further indicated that the STEAM based science busy book received highly positive responses from both teachers and students. The average evaluation score reached 4.45, categorized as "very good," signifying that the media successfully met aspects of engagement, visual appeal, ease of use, and alignment with learning objectives. This result strengthens the findings of Yuliani (2021), who reported that exploration-based interactive

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media can increase children's concentration and curiosity. Children in this study displayed high enthusiasm, active participation, and improved problem-solving skills, such as sequencing patterns or interpreting science phenomena through small scale experiments (Ashadi et al., 2023). This is consistent with Vygotsky's (1978) theory, which underscores the importance of learning tools to optimize children's cognitive development through social interaction and direct experience.

The highest contributing aspects were the visual design, clarity of instructions, and developmental appropriateness of the activities, which aligns with previous findings that visually engaging and developmentally aligned materials significantly enhance young children's engagement and autonomy (Huang & Chou, 2022; Fisher et al., 2013). These strengths suggest that the busy book's layout and child-friendly sequencing effectively support exploratory learning. Conversely, the components with relatively lower though still positive ratings were related to the durability of physical materials and the complexity of certain STEAM tasks, echoing challenges reported in similar manipulative based and STEAM integrated media (Akçayır & Akçayır, 2019; Chen & Wang, 2021). These results imply that future improvements should prioritize strengthening material durability for sustained classroom use and adjusting task complexity to better align with children's cognitive readiness. Refining these aspects would not only enhance usability but could also further improve learning outcomes and overall evaluation scores in subsequent iterations of the busy book (Lestari & Hidayat, 2022; Yakman, 2010).

From the teachers' perspective, the implementation of the busy book was seen as an effective support for making abstract concepts more tangible. Teachers reported that explaining the material became easier as children learned through hands on experiences embedded in each activity. These findings are in line with Chen and Wang (2021), who argued that integrating STEAM into early childhood learning media fosters critical thinking, creativity, and collaboration. Thus, the STEAM based science busy book not only enhanced children's interest in learning but also contributed significantly to the development of their cognitive abilities, critical thinking skills, and readiness for future learning stages.

Within the STEAM framework, early childhood education should emphasize exploration, interdisciplinary integration, and experiential learning rather than rote memorization (Yakman, 2008). The children's observed behaviors during the use of the STEAM based Science Busy Book strongly align with Vygotsky's sociocultural theory, particularly the concept of the Zone of Proximal Development (ZPD). As children interacted with the manipulatives sorting objects, making predictions, testing cause effect relationships, and solving simple mechanical challenges they demonstrated higher level skills that emerged through guided scaffolding from teachers and peers. This pattern reflects Vygotsky's view that cognitive development is stimulated when children engage in meaningful tasks supported by social interaction and appropriate scaffolding, gradually internalizing new concepts through hands on exploration (Vygotsky, 1978). Likewise, the activities align with the STEAM framework proposed by Yakman (2010), in which science, engineering, and the arts are integrated to promote holistic inquiry. The children's engagement in designing small solutions, experimenting with materials, and expressing ideas through multimodal tasks mirrors the interdisciplinary cognitive processes described by Perignat and Katz-Buonincontro (2019). These aligned behaviors imply that STEAM-integrated busy books can create learning environments where scientific reasoning, creativity, and problem-solving develop simultaneously, offering strong pedagogical value for early childhood science education. This reflects the essence of the STEAM approach, which is to encourage cross

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disciplinary thinking and to connect knowledge with everyday life (Perignat & Katz-Buonincontro, 2019).

Furthermore, the implementation results reinforce the argument that a STEAM based approach supports the development of creativity, critical thinking, and problem-solving skills in early childhood (Chen & Wang, 2021). The children not only enjoyed the activities but also demonstrated cognitive improvements in memory, concentration, and their ability to explain observations. Teachers also confirmed that the busy book made the learning process more contextual and meaningful, thereby supporting the broader goals of early childhood education as a foundation for 21st-century skills development. In conclusion, the integration of STEAM theory with the science busy book demonstrates that this medium is not merely an entertaining tool, but an effective pedagogical instrument that nurtures scientific literacy, creativity, and higher order thinking in young learners.

Table 3. Results of the Implementation of the STEAM Based Science Busy Book

STEAM Aspects	Activities in the Busy Book	Children's Cognitive Development	Implementation Results (Scale 1-5)
Science	Observing the colors, shapes, and textures of simple natural objects (e.g., fruits, plants, water).	Children are able to explain differences, recall details, and draw simple conclusions.	4,5
Technology	Using interactive images and picture pieces with Velcro.	Children learn to understand the concept of tool functions and attempt to solve simple technical problems.	4,3
Engineering	Constructing simple structural patterns (e.g., operating a pulley system to reach the intended target).	Children are able to think logically, experiment with solutions, and identify cause-and-effect relationships.	4,4
Arts	Coloring, drawing, and attaching stickers based on science themes.	Children express creativity and imagination while enhancing fine motor coordination.	4,6
Mathematics	Counting objects, sequencing numbers, and matching patterns.	Children develop early numeracy skills, recognize numerical symbols, and classify objects.	4,5
		Total Mean Score	4,46

The implementation results indicate that: (1) Children demonstrated greater enthusiasm in participating in busy book-based learning activities due to their interactive and contextual nature. (2) All aspects of STEAM contributed to cognitive development, with the highest score recorded in Arts (4.6), as children greatly enjoyed creative activities. (3) The overall average score of 4.46 confirms that the STEAM based Science Busy Book is effective as an early childhood learning medium, consistent with the theory that STEAM integration enhances creativity, problem solving, and basic scientific understanding (Perignat & Katz-Buonincontro, 2019; Chen & Wang, 2021).

Evaluation

The evaluation stage was carried out to assess the effectiveness, feasibility, and appropriateness of the STEAM based Science Busy Book in relation to the cognitive development needs of early childhood. The evaluation was conducted in two forms: formative evaluation (during the development process) and summative evaluation (after implementation).

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Formative Evaluation

The formative evaluation was conducted during a limited trial in a kindergarten classroom at TK Labschool IKIP PGRI Jember with a sample of 25 children. Observation results indicated that the children were able to follow the activities in the Science Busy Book effectively. Teachers provided feedback regarding the clarity of instructions, visual appeal, and alignment with the developmental level of the children. This feedback was used as a basis for revision to ensure the product better suited the learning needs of early childhood.

Summative Evaluation

The summative evaluation was conducted after the implementation was completed. Both teachers and children completed assessment instruments that covered cognitive aspects, learning motivation, and child engagement. The results showed that the STEAM based Science Busy Book enhanced children's cognitive abilities, particularly in observation, exploration, and simple problem-solving. The average cognitive assessment score reached 86% (categorized as very good).

Based on the evaluation results, the STEAM based Science Busy Book was declared feasible and effective as a learning medium. This product not only facilitated children's understanding of basic scientific concepts but also integrated elements of technology, engineering, arts, and mathematics into enjoyable activities. These findings align with the view that the STEAM approach enriches early childhood learning experiences and supports the development of critical and creative thinking (Yakman, 2010; Perignat & Katz-Buonincontro, 2019)

Table 4. Evaluation Results of the STEAM Based Science Busy Book

Evaluation Aspects	Mean Score (%)	Category
Alignment with Objectives	88%	Very Good
Material Feasibility	85%	Very Good
Layout and Design	87%	Very Good
Child Appeal	89%	Very Good
Cognitive Development	86%	Very Good
Mean	**87%**	**Very Good**

The evaluation results indicate that the STEAM based Science Busy Book is highly effective in enhancing engagement and cognitive development in early childhood. An average assessment score of 87%, categorized as excellent, suggests that this learning media aligns well with the educational needs of children at TK Labschool IKIP PGRI Jember. These findings support previous studies demonstrating that interactive learning media can boost learning interest and provide meaningful experiences for young learners (Nurhayati, 2021; Setiawan & Rahayu, 2020).

From the STEAM approach perspective, summative evaluation revealed that the integration of multiple disciplines (science, technology, engineering, arts, and mathematics) in the Busy Book helps children grasp concepts more concretely. Children are not merely memorizing information; they actively engage in exploration, simple experiments, and creativity demanding activities. This aligns with Yakman's (2010) theory, which emphasizes that STEAM provides children with holistic learning experiences that foster critical, collaborative, and creative thinking from an early age.

Furthermore, the evaluation results indicate that teachers perceive the Busy Book as beneficial in facilitating the teaching process. Educators can use this media to bridge abstract concepts into tangible forms through visual and manipulative activities. This perspective corroborates Perignat and Katz Buonincontro (2019), who argue that STEAM approaches enhance instructional quality by connecting theory and practice while enabling children to

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learn actively. Therefore, the STEAM based Science Busy Book proves not only cognitively effective but also relevant as an innovative learning medium for early childhood education.

In the context of early childhood education, the findings of this study offer important contributions to children's cognitive, motor, linguistic, and socio emotional development. The STEAM-based Science Busy Book was found to effectively stimulate foundational scientific inquiry skills such as observing, comparing, predicting, and understanding cause effect relationships which are considered essential components of early science learning (Fisher et al., 2013; Chen et al., 2023). Through concrete, hands on activities, young children learn by directly manipulating materials and engaging in exploratory play, a process aligned with constructivist developmental principles emphasized by Vygotsky (1978) and supported by research on guided play and experiential learning (Fisher., K., Hirsh-Pasek & Golinkoff, 2013).

Furthermore, the integration of STEAM elements within the busy book provides opportunities for children to develop creativity, problem solving abilities, and fine motor coordination through tasks that involve assembling, sliding, opening and closing mechanisms, and connecting objects. Prior studies have demonstrated that concrete manipulatives significantly enhance fine motor skills and visual spatial abilities in early childhood (Huang & Chou, 2022; Kaya & Yilmaz, 2022). However, the present study offers additional value not widely reported in earlier research, particularly the strengthening of early engineering thinking and predictive reasoning, both of which typically emerge during preschool years when children are exposed to simple, problem-driven exploratory tasks (Bers, 2022; Yakman, 2010).

From a socio-emotional perspective, children showed increased confidence and curiosity as they successfully completed tasks within the busy book independently. This aligns with findings by Han and Bhattacharya (2022), who highlight that STEAM-based learning media promote autonomy, exploration, and self-directed engagement in young learners. Thus, the design of the STEAM based Science Busy Book in this study directly supports the developmental characteristics of early childhood learning, which are inherently exploratory, multisensory, and experience-driven.

Conclusion

The findings of this study demonstrate that the STEAM based Science Busy Book is effective in enhancing early childhood cognitive abilities, fine motor skills, and foundational scientific inquiry skills. Through well-structured manipulative activities, children were able to show improvements in observation, classification, prediction, simple problem solving, and understanding cause effect relationships. The expert validation and user response score of 4.45 (Very Good) confirms that the visual design, clarity of instructions, and developmental appropriateness of the activities are among the strongest features of the media.

The meaning of these findings reinforces that integrating STEAM elements into a busy book not only increases engagement and motivation but also provides an early foundation for scientific and engineering thinking. Activities that combine science, simple technology, engineering, art, and mathematics allow children to learn holistically. Furthermore, the observation that children performed better when provided with appropriate scaffolding aligns with Vygotsky's theory, which highlights the role of social support in maximizing cognitive development. In conclusion, the STEAM based Science Busy Book is feasible, valid, and effective as an early childhood learning medium, supporting the development of scientific literacy in an interactive and meaningful way.

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Recommendation

Based on the research and development of the STEAM based Science Busy Book, several recommendations can be proposed as follows: (1) Teachers are encouraged to utilize the STEAM based Science Busy Book as an interactive learning medium. It can be applied not only in science lessons but also to integrate concepts of technology, engineering, arts, and mathematics through creative and enjoyable activities. (2) Schools are expected to support the use of this innovative media by providing facilities and opportunities for teachers to develop similar media. The Busy Book can serve as a model for developing other learning media tailored to the needs and characteristics of young children. (3) Further research can expand the sample to include more diverse schools to assess the effectiveness of the media in different contexts. Additionally, subsequent studies can examine the impact of using the STEAM based Science Busy Book on other developmental aspects, such as socio-emotional skills, language, and children's motor skills.

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