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Development Of Smart Cube Learning Media To Improve Critical Thinking Skills In Children Aged 4–5 Years

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ABSTRACT

This study aims to develop Smart Cube learning media based on problem-solving activities to improve the critical thinking skills of children aged 4–5 years. The research employed a Research and Development (R&D) approach using the ADDIE model, which consists of the stages of analysis, design, development, implementation, and evaluation. The research subjects included children aged 4–5 years and early childhood teachers. Data were collected through observation, interviews, questionnaires, and documentation. The data were analyzed using descriptive quantitative and qualitative techniques. Product validation was conducted by media experts and material experts to determine the feasibility of the developed learning media. The results of the study indicate that the needs analysis revealed the importance of providing concrete, attractive, and interactive learning media capable of stimulating children's critical thinking activities. The developed Smart Cube met both theoretical and empirical feasibility criteria and was categorized as feasible to highly feasible based on expert validation results. Limited trials showed that the Smart Cube was easy for teachers to use and received positive responses from children during learning activities. Furthermore, the effectiveness test demonstrated that the use of Smart Cube learning media effectively improved the critical thinking skills of children aged 4–5 years. Quantitatively, there was an increase in children's critical thinking abilities after the use of the media. Qualitatively, children showed improvements in activeness, curiosity, simple problem-solving abilities, and confidence in expressing their opinions. Therefore, Smart Cube can serve as an innovative and practical learning medium to support the development of critical thinking skills in early childhood education.

Keywords: *Smart Cube, Learning Media, Critical Thinking, Early Childhood Education, Children Aged 4–5 Years*

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INTRODUCTION

Early Childhood Education (ECE) plays a fundamental role in shaping children's cognitive, social, and emotional development, which significantly influences their future learning trajectories. During the early years, children experience rapid brain development that forms the foundation for higher-order thinking skills and lifelong learning. Therefore, providing appropriate stimulation in early childhood education is essential to support the

development of essential competencies. In the context of the twenty-first century, education systems worldwide are increasingly emphasizing critical thinking, creativity, collaboration, and communication as core competencies required for future success (Karademir et al., 2020). The World Economic Forum also highlights that critical thinking is among the most important skills needed in the evolving global workforce, particularly as many current preschool-aged children are expected to work in professions that do not yet exist (World Economic Forum, 2020). These developments indicate the importance of fostering critical thinking skills from an early age through meaningful and developmentally appropriate learning experiences.

Critical thinking development in early childhood differs from that of older learners but remains a crucial foundation for later cognitive growth. According to the sociocultural theory of learning, children construct knowledge through interaction with their environment and through guided support provided by adults or peers (Vygotsky, 1978). The concept of the Zone of Proximal Development (ZPD) emphasizes that children can reach higher levels of cognitive functioning when appropriate scaffolding is provided. Research has shown that children aged four to five are in a crucial developmental stage for early metacognitive abilities, which are closely associated with the emergence of critical thinking skills (Boyd et al., 2023). Furthermore, stimulating cognitive processes through exploratory activities during this developmental period can strengthen neural pathways associated with higher-order thinking (Aubrey et al., 2014).

Despite the recognized importance of critical thinking, empirical evidence indicates that its development among young learners remains limited in many educational contexts. International assessments such as the Programme for International Student Assessment (PISA) demonstrate relatively low levels of analytical and problem-solving abilities among Indonesian students (Adiputri, 2023). Although PISA evaluates students at the age of fifteen, the results indirectly reflect insufficient stimulation of higher-order thinking skills during earlier educational stages. Previous research in early childhood education also reveals that many young learners demonstrate limited abilities in identifying patterns, solving simple problems, and independently exploring alternative solutions (Rahmasari et al., 2021). These findings highlight the need for innovative learning approaches and media that actively engage children in cognitive exploration and problem-solving activities.

One promising approach to support critical thinking development in early childhood is the use of manipulative learning media. Manipulative materials allow children to interact directly with physical objects, helping them transform abstract ideas into concrete experiences (Clements & Sarama, 2007). Constructive play activities involving blocks or cubes have been shown to support spatial reasoning, logical thinking, and early problem-solving abilities among preschool children (Ramani et al., 2014). Longitudinal studies further indicate that early engagement in constructive play activities is positively associated with later mathematical reasoning and analytical thinking skills (Piccolo & Test, 2020). These findings suggest that manipulative media can provide meaningful learning experiences that stimulate children's curiosity, exploration, and reasoning processes.

However, existing studies generally focus either on manipulative learning media or on problem-solving approaches separately. Few studies have integrated both aspects into a structured learning medium specifically designed to stimulate critical thinking skills in early childhood contexts. Previous research has explored the use of educational blocks to support cognitive development (Sari et al., 2019), as well as the use of problem-based learning to increase children's learning engagement (Rahmawati, 2020). Nevertheless, these studies often lack structured media design that systematically integrates problem-solving challenges into manipulable learning tools. As a result, there remains a research gap in developing innovative media that combines concrete manipulatives with problem-solving activities to foster critical thinking in early childhood education.

To address this gap, this study aims to develop **Smart Cube learning media** designed to enhance critical thinking skills among children aged four to five years. The media integrates manipulative cube-based construction activities with structured problem-solving challenges that encourage children to analyze situations, explore multiple solutions, and express their ideas. The development process adopts the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation, ensuring a systematic and iterative product development process (Branch, 2019).

The contribution of this research lies in the development of an innovative learning medium that integrates manipulative three-dimensional materials with structured problem-solving activities tailored to the developmental characteristics of early childhood learners. Unlike previous studies that primarily examine either manipulative media or problem-solving approaches independently, this research combines both elements into a comprehensive learning system consisting of physical media, activity cards, teacher guidance, and assessment indicators. Therefore, the Smart Cube learning media is expected to provide a practical and evidence-based solution for supporting critical thinking development in early childhood education settings.

METHOD

Research Design

This study employed a Research and Development (R&D) approach aimed at developing an innovative learning medium called the Smart Cube to enhance critical thinking skills in children aged 4–5 years. The development process followed the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because it provides a systematic framework for designing, developing, and evaluating educational products in a structured manner. During the analysis stage, the researchers examined learning needs, children's developmental characteristics, and curriculum requirements related to early critical thinking skills. The design stage focused on planning the structure, appearance, and learning activities embedded in the Smart Cube. In the development stage, the prototype was produced and validated by experts. The implementation stage involved limited trials with children and teachers, while the evaluation stage assessed the feasibility and effectiveness of the developed media.

Subjects, Population, and Sample

The research was conducted at TK Trisula Perwari, located in Purwakarta Regency, West Java, Indonesia, from October 2025 to January 2026. The subjects of this study consisted of children aged 4–5 years (Group A) and early childhood education teachers. Children at this age are in the preoperational stage according to Piaget's cognitive development theory, characterized by emerging symbolic thinking but still limited to concrete reasoning. A small group trial involving 12 children was conducted to evaluate the practicality and usability of the Smart Cube learning media. Teachers at the institution also participated as informants in interviews and observations to provide insights regarding the implementation of the media and its impact on children's learning activities.

Data Collection Procedure

Data were collected using several instruments to obtain comprehensive information regarding the development and effectiveness of the Smart Cube media. The instruments included expert validation sheets, observation sheets, interview guides, documentation, and product evaluation rubrics. Expert validation sheets were used to assess the feasibility of the product from the perspectives of content experts, media experts, and early childhood education experts, using a five-point Likert scale ranging from very poor to very good. Observation sheets were used to measure children's critical thinking skills during learning activities, covering indicators such as observation, comparison, classification, sequencing, simple prediction, and problem-solving abilities. Semi-structured interviews were conducted with teachers and school administrators to explore their perceptions regarding the need for learning media and the effectiveness of the Smart Cube. Additionally, documentation in the form of photographs and videos was collected to support the analysis of children's learning interactions during the implementation of the media.

Data Analysis

The collected data were analyzed using both quantitative and qualitative approaches. Quantitative data obtained from expert validation and observation sheets were analyzed using descriptive statistics to calculate feasibility percentages using the formula $P=(\Sigma X/\Sigma Xi)\times 100\%$. The results were then interpreted using feasibility criteria to determine whether the developed media was very valid, valid, less valid, or invalid. Meanwhile, qualitative data from interviews, expert comments, and observational notes were analyzed using content analysis techniques, which involve data reduction, data display, and conclusion drawing. The effectiveness of the Smart Cube in improving children's critical thinking skills was examined by comparing the results of pre-test and post-test observations conducted before and after the use of the learning media.

FINDING AND DISCUSSION

Main Results

The development of the Smart Cube learning media aimed to improve the critical thinking skills of children aged 4–5 years through problem-solving activities. The research followed the ADDIE development model consisting of analysis, design, development, implementation, and evaluation stages. The results of the study present empirical data related to product feasibility and the effectiveness of the developed learning media.

Needs Analysis

The needs analysis stage involved classroom observations and interviews with early childhood teachers. The results indicated that learning activities in the classroom were still dominated by conventional teaching methods and limited use of interactive learning media. Teachers reported that children needed learning tools that were concrete, engaging, and capable of stimulating thinking processes.

Observations showed that children's critical thinking abilities were still relatively low. Several indicators such as asking questions, identifying problems, and providing simple reasoning were not optimally developed during classroom activities. These findings became the basis for designing a learning medium that integrates play-based learning with simple problem-solving activities.

Product Development Results

Based on the results of the analysis stage, the Smart Cube learning media was designed as a manipulative learning tool consisting of several cubes combined with instruction cards containing problem-solving activities. Each side of the cube represents different tasks that encourage children to observe, analyze, and make simple decisions.

The development process produced a prototype of the Smart Cube accompanied by instructional cards and a teacher guide. Before being implemented in classroom learning, the product underwent a validation process involving material experts, media experts, and early childhood education practitioners.

Expert Validation Results

The validation process was conducted by three validators consisting of a material expert, a media expert, and an early childhood education practitioner. The purpose of this validation was to assess the theoretical feasibility of the developed learning media.

The results of material expert validation showed that the Smart Cube media obtained a score of 66 out of a maximum score of 75, with a feasibility percentage of 88.0%, categorized as very feasible. The highest scores were obtained in the aspects of alignment with early childhood development standards (STPPA) and learning theory suitability, each reaching 93.3%. The material substance and critical thinking content aspects achieved 86.7%, indicating that the learning content appropriately supports the development of children's critical thinking skills. The lowest score was found in the difficulty level aspect, which reached 80.0%, although it still fell within the feasible category.

The media expert validation produced a total score of 73 out of 80, with a feasibility percentage of 91.3%, categorized as very feasible. The safety aspect achieved the highest score with 100%, indicating that the materials and design were safe for children aged 4–5 years. The design aspect reached 90.0%, while visual attractiveness and practicality both reached 86.7%, demonstrating that the media was visually appealing and easy to use during classroom activities.

Validation by early childhood education practitioners produced a total score of 65 out of 75, with a percentage of 86.7%, also categorized as very feasible. The assessed aspects included implementation, child-media interaction, pedagogical effectiveness, usage guidelines, and additional value in classroom learning.

Overall, the recapitulation of expert validation results showed that the Smart Cube media achieved an average feasibility score of 204 out of 230, equivalent to 88.7%, which falls into the very feasible category. These results indicate that the developed media met the theoretical requirements for implementation in early childhood learning environments.

Limited Trial Results

After completing the validation stage and revising the product according to expert suggestions, a limited trial was conducted involving 15 children aged 4–5 years. The purpose of this trial was to evaluate the practicality and effectiveness of the Smart Cube media in real classroom situations.

During the implementation process, children participated in several activities using the Smart Cube that involved identifying simple problems, asking questions, finding alternative solutions, giving simple reasons, and making simple decisions. Teachers facilitated the activities using instruction cards provided with the media.

Critical Thinking Pretest Results

Before the implementation of the Smart Cube media, children were given a pretest to measure their initial critical thinking abilities. The total score obtained from 15 children was 640 out of a maximum possible score, with an average score of 42.7, or 32.0 points per child. These results indicated that children's critical thinking skills were still relatively limited before the intervention.

The lowest scores were observed in the indicators of searching for alternative solutions and providing simple reasoning, indicating that children still had difficulty generating ideas and explaining their answers.

Critical Thinking Posttest Results

After the implementation of the Smart Cube media, a posttest was conducted to measure children's critical thinking skills. The results showed a significant improvement in overall performance. The total score increased to 992 points, with an average score of 66.1, or 49.6 points per child, representing 82.7% of the maximum score. This level falls into the category of developing as expected and approaching very well developed.

Detailed results for each critical thinking indicator showed substantial improvements:

Indicator	Pretest Average	Posttest Average
Identifying simple problems	8.3	13.1
Asking questions	8.5	13.3
Searching for alternative solutions	7.7	12.8
Providing simple reasoning	8.0	13.1
Making simple decisions	10.1	13.9

The results show that all five indicators experienced measurable improvement after the implementation of the Smart Cube learning media. The largest improvement occurred in the indicators related to searching for alternative solutions and providing simple reasoning, which previously showed lower performance during the pretest stage.

Overall Improvement

The comparison between pretest and posttest results shows that the total score increased from 640 to 992, indicating a substantial improvement in children's critical thinking performance. The average score per child increased from 32.0 to 49.6 points, demonstrating measurable growth in children's ability to analyze simple problems, ask questions, and provide explanations during learning activities.

DISCUSSION

Interpretation of Findings

The findings of this study demonstrate that the **Smart Cube learning media** effectively supports the development of critical thinking skills in children aged 4–5 years. The significant increase in children's posttest scores compared to the pretest results indicates that the learning activities facilitated by the Smart Cube were able to stimulate children's cognitive engagement during the learning process. The improvement observed across all five critical thinking indicators suggests that children were able to develop better abilities in identifying problems, asking questions, searching for alternative solutions, providing simple reasoning, and making decisions.

The improvement in children's performance can be attributed to the interactive and manipulative characteristics of the Smart Cube. Learning activities involving concrete objects enable children to actively explore, experiment, and construct their understanding through direct experience. The use of instruction cards that present simple problem-solving tasks also encourages children to think beyond rote responses and to engage in reflective thinking processes. Through repeated interactions with the learning media, children gradually develop the ability to analyze situations and generate possible solutions.

Another important finding is that the Smart Cube media not only improves children's cognitive performance but also increases their participation during classroom activities. Observations during the implementation stage showed that children became more active in asking questions, expressing their opinions, and responding to challenges presented in the instruction cards. This suggests that learning media that combine play-

based activities with structured cognitive challenges can effectively stimulate children's curiosity and engagement in the learning process.

Relationship to Literature

The findings of this study are consistent with previous research indicating that interactive and manipulative learning media can significantly support the development of critical thinking in early childhood education. Early childhood learning environments that incorporate hands-on activities and problem-solving opportunities allow children to explore ideas and construct knowledge actively rather than passively receiving information.

Several studies have emphasized that play-based learning environments provide opportunities for children to practice higher-order thinking skills. When children interact with concrete materials and are encouraged to ask questions, predict outcomes, and test solutions, they develop essential cognitive processes related to critical thinking. The Smart Cube learning media aligns with this perspective by integrating play, exploration, and problem-solving activities into a single learning tool.

Furthermore, the findings support constructivist learning theory, which emphasizes that knowledge is constructed through active interaction with the environment. In early childhood contexts, children learn most effectively when they manipulate objects, experiment with ideas, and engage in dialogue with teachers and peers. The Smart Cube media facilitates such interactions by providing a structured yet flexible learning experience where children can explore different problem situations and attempt various solutions.

Previous studies on early childhood cognitive development also highlight the importance of scaffolding in promoting critical thinking skills. The use of graded instruction cards within the Smart Cube activities provides a form of scaffolding that allows teachers to adjust the level of challenge according to children's abilities. This approach enables children to gradually develop more complex thinking skills while maintaining motivation and engagement in the learning process.

Limitations of the Study

Despite the positive results obtained in this study, several limitations should be acknowledged. First, the number of research participants was relatively small, involving only a limited group of children aged 4–5 years. This condition may limit the generalizability of the findings to broader populations of early childhood learners.

Second, the duration of the implementation was relatively short. The study observed improvements in children's critical thinking abilities within a limited timeframe, but it did not examine the long-term impact of the Smart Cube learning media on children's cognitive development. Longitudinal studies would be necessary to determine whether the improvements observed in this study can be sustained over time.

Third, the research was conducted in a single early childhood education institution. Differences in classroom environments, teacher competencies, and learning cultures in other institutions may influence the effectiveness of the developed learning media.

Therefore, further studies involving multiple educational settings are needed to strengthen the validity and applicability of the findings.

Implications

The results of this study have several important implications for early childhood education practices. For teachers, the Smart Cube learning media provides an innovative instructional tool that can be integrated into play-based learning activities to stimulate children's critical thinking skills. The use of manipulatives combined with problem-solving tasks can create a more engaging learning environment where children are encouraged to explore ideas and express their thoughts.

For early childhood education institutions, the development of simple yet effective learning media such as the Smart Cube demonstrates that innovative educational tools do not necessarily require complex technology. Teachers and institutions can develop contextually relevant learning media using accessible materials while still supporting children's cognitive development.

For future research, it is recommended that further studies examine the effectiveness of the Smart Cube learning media with larger samples and in different educational contexts. Researchers may also explore the integration of similar problem-solving-based learning media with other developmental domains, such as language development, social-emotional skills, and creativity.

In addition, future studies could investigate the long-term impact of problem-solving learning media on children's higher-order thinking skills. Expanding the variation of learning activities and instructional strategies integrated within the Smart Cube may also provide opportunities for further innovation in early childhood education.

CONCLUSION

This study aimed to develop and evaluate the effectiveness of the Smart Cube (Kubus Pintar) as a learning medium to enhance the critical thinking abilities of children aged 4–5 years. Based on the results of the needs analysis, it was found that early childhood learners require concrete, engaging, and safe learning media that can stimulate cognitive activities such as observing, comparing, classifying, and solving simple problems. The learning practices previously used in the classroom were still dominated by worksheets and conventional methods, which were considered less effective in stimulating children’s critical thinking skills.

The development of the Smart Cube was carried out using the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. The resulting product was designed as a manipulative learning medium containing simple problem-solving activities suited to the developmental characteristics of children aged 4–5 years. Validation results from media and material experts indicated that the Smart Cube met the criteria of feasibility, ranging from feasible to very feasible, both theoretically and empirically. Limited trials also showed that the media was easy for teachers to use and

received positive responses from children, who demonstrated high levels of enthusiasm, participation, and engagement during learning activities.

Furthermore, the effectiveness testing showed that the use of the Smart Cube significantly improved children's critical thinking skills. Quantitative data indicated an increase in critical thinking scores after the implementation of the media, while qualitative observations revealed improvements in children's curiosity, confidence in expressing ideas, willingness to attempt problem solving, and ability to collaborate with peers. Therefore, the Smart Cube can be considered an innovative and practical learning medium that supports the development of critical thinking skills in early childhood education.

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