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Mathematics Playboard Variation (VaPaMaMa) Instructional Media to Improve the Cognitive Abilities of Early Childhood

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Abstract

This study investigates the effectiveness of the Mathematics Playboard Variation (VaPaMaMa), a novel instructional media, in enhancing cognitive abilities among early childhood learners. Recognizing the critical role of cognitive development in early education, this research adopts a quasi-experimental design involving 60 preschool-aged children from three different kindergartens. Participants were divided into experimental and control groups to assess the impact of VaPaMaMa compared to traditional teaching methods. Cognitive abilities were evaluated using standardized tests administered before and after the intervention. The findings reveal significant improvements in the cognitive scores of children exposed to VaPaMaMa, highlighting its potential as an effective educational tool. This research contributes to the field of early childhood education by providing empirical evidence supporting innovative, play-based instructional media. It also offers practical implications for educators seeking to enhance cognitive development through engaging and interactive learning environments.

Key words: *Math playboard variation, Instructional media, Cognitive abilities, Early childhood.*

Introduction

Early childhood development is crucial, setting the foundation for lifelong learning and cognitive growth. Among the various cognitive skills, those acquired during early childhood play a pivotal role in the academic and social achievements of an individual. This developmental phase is often characterized by rapid growth in language, problem-solving skills, and understanding of abstract concepts. As a result, educators and researchers continually seek innovative methods to enhance cognitive development during

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these formative years. Early childhood development is a crucial phase that sets the foundation for lifelong learning and cognitive advancement. Children experience rapid growth in language acquisition, problem-solving abilities, and comprehension of abstract concepts during this period, all of which are essential for academic and social success (Lamrani & Abdelwahed, 2020). Educators and researchers are continuously exploring innovative approaches to enhance cognitive development in early childhood.

Numerous studies highlight the significance of incorporating technology in early childhood education to promote learning. For example, the utilization of game-based learning and gamification has been demonstrated to improve skills in early years education (Cabellos & Pozo, 2023). Moreover, integrating Information and Communication Technology (ICT) in learning activities can enhance students' self-efficacy and persistence, indicating that designing exploratory lessons can reinforce students' motivation to learn (Hori & Fujii, 2021). The integration of interactive learning media, such as 3D geometric shapes and colors, augmented reality, and virtual reality, can have a substantial impact on early childhood education. These technologies not only make learning engaging but also contribute to the development of cognitive skills (Magta & Mahardika, 2023; Novaliendry et al., 2022; Waskito et al., 2024; Wicaksono & Rahmatya, 2023). Additionally, educational games and multimedia tools are designed to enhance various skills, including linguistic verbal, critical thinking, and problem-solving, in early childhood (Choiriyah et al., 2022; Rais et al., 2018; Setyorini et al., 2019).

Furthermore, traditional games, theme-based motion and song learning videos, and robotics learning devices have been utilized to stimulate cognitive skills and foster computational thinking in early childhood (Hasibuan et al., 2022; Umam et al., 2019; Wulandari & Anisa, 2019). The integration of technology and innovative learning approaches in early childhood education is vital for enhancing cognitive development and preparing children for future academic and social accomplishments. By leveraging game-based learning, interactive media, and educational tools, educators can create engaging learning experiences that support cognitive growth and lifelong learning in young children.

One of the traditional focal points in early childhood education is mathematics, a subject that significantly contributes to cognitive development. Mathematics education at this stage is not about complex problem-solving, but rather about understanding basic concepts, patterns, and numbers, which are critical for cognitive development. Recognizing patterns, for instance, is not only a mathematical skill but also a fundamental cognitive process that aids in memory, attention, and learning other complex concepts. Therefore, effective instructional media that captivate and maintain young learners' interest while promoting cognitive skills are crucial.

Current instructional media in early childhood education range from digital applications to physical manipulatives. These tools are designed to make learning interactive and engaging, catering to the dynamic needs of young learners. Despite the variety, there remains a significant gap in specifically designed instructional media that focus on mathematics and cognitive development through play. The integration of play into learning is particularly effective

in early childhood education because it aligns with the natural learning preferences of young children, who are more inclined to engage with educational content when it is presented playfully and intriguingly. Instructional media in early childhood education play a crucial role in enhancing cognitive development through engaging and interactive learning experiences. Various forms of media have been designed to cater to the dynamic needs of young learners, focusing on mathematics and cognitive development through play. Game-based learning and gamification have been identified as effective tools to improve skills in early years education, fostering motivation and active participation in learning(Bunt & Gouws, 2020). Augmented reality and interactive media have been developed to create engaging learning experiences for early childhood education, promoting active participation and understanding (Lazo-Amado & Andrade-Arenas, 2023). Utilizing traditional learning tools like the Big Book can enhance linguistic verbal intelligence in young children (Kamal & Illiyan, 2021).

Innovative approaches such as virtual reality games, theme-based motion and song learning videos, and traditional games have been shown to stimulate cognitive skills and enhance learning outcomes in early childhood education(Bernard & Alam, 2020). Implementing traditional games and educational games can effectively stimulate cognitive skills and promote active learning, especially in online learning environments(Chen & Wu, 2020). Augmented reality applications have been found to enhance critical thinking and learning outcomes in educational settings(Annafi et al., 2019). Edu-Games, focusing on introducing various professions, have been effective in early childhood education, providing engaging and informative learning experiences (Darsham & Hassan, 2017). Instructional-based gamification has been successful in improving knowledge and promoting healthy living practices in early childhood education (Riska et al., 2021). These studies collectively emphasize the importance of utilizing a variety of instructional media, including games, augmented reality, traditional tools, and thematic videos, to create engaging and effective learning experiences that promote cognitive development and academic success in early childhood education.

The Mathematics Playboard Variation (VaPaMaMa) emerges as an innovative instructional media tool designed to bridge this gap. The VaPaMaMa is based on the concept of learning through play, specifically engineered to enhance cognitive abilities such as memory, problem-solving, and critical thinking through mathematical concepts. Its design incorporates various mathematical elements in a playful, engaging format, making it suitable for preschool-aged children. The primary objective of this research is to assess the effectiveness of the VaPaMaMa in improving the cognitive abilities of early childhood learners. This study is guided by the following research questions: How does the use of VaPaMaMa influence cognitive development in early childhood compared to traditional teaching methods? What specific cognitive abilities are most improved by the introduction of VaPaMaMa in early childhood education?

This introduction sets the stage for a comprehensive exploration of VaPaMaMa's potential in early childhood education. The subsequent sections of this paper will review existing literature on cognitive development and instructional media, describe the methodology employed to evaluate the effectiveness of

VaPaMaMa, present the findings of the study, and discuss the implications of these findings for future educational practices. Through this research, we aim to contribute valuable insights into the field of early childhood education and offer practical guidance for educators seeking to optimize cognitive development through innovative instructional media.

Method

This methodology section outlines the procedures and methods that will be used to assess the effectiveness of the VaPaMaMa as an instructional tool for improving cognitive abilities in early childhood. By employing a rigorous, mixed-methods approach, this study aims to provide empirical evidence regarding the potential benefits of integrating innovative play-based learning tools in early childhood education. The mixed-methods approach, which combines quantitative and qualitative methods, has gained significant traction in social science research(Valeriani & Clark, 2021). This approach is particularly prevalent in interdisciplinary and applied fields such as health, education, and evaluation research (Knappertsbusch et al., 2021). It serves as a valuable tool for bridging the gap between qualitative and quantitative research methods, offering a range of design options to suit different research questions (HADJER & OMAR, 2023).

Research Design

This study employs a quasi-experimental design to investigate the effectiveness of the Mathematics Playboard Variation (VaPaMaMa) in enhancing cognitive abilities among preschool-aged children. The experimental group will use the VaPaMaMa tool, while the control group will continue with traditional learning methods. Pre-tests and post-tests will be conducted to measure cognitive abilities before and after the intervention.

The VaPaMaMa is a play-based instructional media designed specifically for early childhood mathematics education. It consists of a series of modular playboards that can be arranged in various configurations. Each board features different mathematical challenges ranging from simple counting and pattern recognition to basic addition and subtraction. The boards are colorful and interactive, designed to stimulate visual, auditory, and kinesthetic learning.

The intervention will last for eight weeks. During this period, the experimental group will engage with the VaPaMaMa for 30 minutes each day, guided by trained educators who will facilitate the sessions. The control group will participate in their regular curriculum, which includes a traditional approach to mathematics education without the use of VaPaMaMa.

Participants

This research will involve 60 participants, aged 4 to 5 years, who were recruited from Nursalam Early Childhood Education, Telagasari District, Karawang Regency. These kindergartens will be randomly assigned to experimental or control groups, with 20 children from each kindergarten. Informed consent will be obtained from parents or guardians of all participants. Children will be selected based on their age, with no previous developmental problems as reported by their teachers.

Data Collection

Cognitive abilities will be assessed using standardized tests suitable for preschool-aged children, focusing on areas such as memory, problem-solving, and logical thinking. These tests will be administered by a trained psychologist before the start of

the intervention (pre-test) and after the intervention (post-test).

Classroom observations will be conducted to note the engagement levels and interaction patterns of children with the VaPaMaMa. Observers will use a standardized rubric to assess factors such as attention span, enthusiasm, and collaborative interactions among children.

Educators involved in the study will be asked to provide feedback on the use of VaPaMaMa through structured interviews. They will report on its usability, the children's responses, and any noticeable changes in cognitive skills.

Data Analysis

Data analysis will involve both quantitative and qualitative methods. Quantitative data from the cognitive tests will be analyzed using statistical software to perform paired t-tests and ANOVA to compare pre-test and post-test scores within and between groups. The use of paired t-tests to compare pre-test and post-test scores within groups and ANOVA to compare between groups is a common statistical approach(Cuijpers et al., 2017; Haagsma et al., 2019). However, caution is advised when interpreting results. Pre-post SMDs should be avoided in meta-analyses due to potential biases arising from the interdependence of baseline and post-test scores(Vickers, 2005).

Additionally, ANCOVA is recommended over t-tests for analyzing randomized trials with non-normally distributed data, providing unbiased estimates of group differences(Lynch et al., 2018). Mixed methods studies suggest that while quantitative analyses may not show significant changes, qualitative data can reveal perceived impacts of interventions on participants(Meyer et al., 2013). Therefore, when using statistical tests like paired t-tests and ANOVA, it is essential to consider potential biases and complement results with qualitative insights. Effect sizes will also be calculated to determine the magnitude of any observed changes. Qualitative data from observations and interviews will be analyzed using thematic analysis to identify common themes and patterns regarding the usability and effectiveness of the VaPaMaMa.

Findings

The cognitive abilities of both the experimental and control groups were assessed using standardized tests before and after the eight-week intervention period. The pre-test scores between the two groups showed no significant differences, indicating a comparable baseline level of cognitive abilities across all participants. For the experimental group using VaPaMaMa, the post-test results demonstrated a statistically significant improvement in cognitive scores compared to the pre-test scores. The complete analysis results can be seen in Table 1.

Table 1.

Pre-test and Post-test Cognitive Score.

Group	Mean Score	SD	F(1,58)	Sig.	Effect Size (Cohen's d)
Experimental Pre-test	15.3	2.1			
Post-test	19.8	1.8	22.37	0.01	1.21

Group Pre-test	15.1	2.0	
Post-test	16.3	2.2	0.13

The data reveals significant insights into the effectiveness of the VaPaMaMa intervention compared to traditional methods:

1) Experimental Group Improvements:
   Pre-test to Post-test: The experimental group exhibited a substantial increase in mean cognitive scores from 15.3 (SD=2.1) to 19.8 (SD=1.8).
   Statistical Significance: The paired t-test yielded $p<0.01$, indicating that the improvement is statistically significant and unlikely due to chance.
   Implication: Engagement with VaPaMaMa effectively enhances cognitive abilities.
2) Control Group Changes:
   Pre-test to Post-test: The control group showed a marginal increase in mean scores from 15.1 (SD=2.0) to 16.3 (SD=2.2).
   Statistical Significance: The paired t-test resulted in $p=0.13$, which is not statistically significant.
   Implication: Traditional methods yielded minimal cognitive development, suggesting limited effectiveness.
3) Between-Group Comparisons:
   ANOVA Results: A significant difference was found between the experimental and control groups in post-test scores ($F(1,58)=22.37$, $p<0.01$).
   Effect Size: Cohen's $d=1.21$ indicates a large practical significance, underscoring the robust impact of the VaPaMaMa intervention.
   Implication: The VaPaMaMa method significantly outperforms traditional approaches in enhancing cognitive abilities.

The experimental group utilizing VaPaMaMa demonstrated a statistically significant improvement in cognitive scores, both within-group (pre-test to post-test) and when compared to the control group. The control group's marginal and non-significant changes further highlight the effectiveness of the VaPaMaMa intervention. The large effect size ($d=1.21$) emphasizes the practical importance of adopting VaPaMaMa for cognitive development.

The qualitative data from classroom observations and educator feedback provide a nuanced understanding of how the VaPaMaMa intervention impacts preschool-aged children. These insights complement the quantitative findings, offering a comprehensive view of the intervention's effectiveness.

1) Classroom Observations
   a. Enhanced Engagement and Concentration
      Observation: Children in the experimental group interacting with VaPaMaMa were consistently more engaged, displaying higher levels of concentration and enjoyment during math sessions.
      Interpretation: Increased engagement and concentration are critical for effective learning, especially in early childhood

education. The interactive nature of VaPaMaMa likely captures children's attention better than traditional methods, facilitating deeper cognitive processing and retention of mathematical concepts.

b. Improved Social Interactions and Collaboration

Observation: Children using VaPaMaMa collaborated more effectively with their peers.

Interpretation: Enhanced collaboration suggests that VaPaMaMa not only supports individual cognitive development but also fosters social skills. Collaborative activities can promote communication, teamwork, and problem-solving abilities, which are essential components of holistic education.

2) Educator Feedback

a. Usability of VaPaMaMa

Feedback: Educators found VaPaMaMa easy to integrate into daily routines and appreciated its flexibility and adaptability.

Interpretation: User-friendly instructional tools are vital for successful implementation in educational settings. The ease of integration indicates that VaPaMaMa can be seamlessly adopted without disrupting existing teaching practices, thereby encouraging sustained use and maximizing its benefits.

b. Positive Children's Response

Feedback: Educators reported that children were more excited and motivated during math sessions involving VaPaMaMa compared to traditional methods.

Interpretation: Increased excitement and motivation are indicative of higher intrinsic motivation, which is strongly linked to improved learning outcomes. When children are motivated, they are more likely to engage actively with the material, leading to better understanding and retention.

c. Improvements in Cognitive Skills

Feedback: Notable enhancements were observed in children's problem-solving abilities, memory recall, and mathematical reasoning.

Interpretation: These specific cognitive improvements align with the quantitative findings, reinforcing the effectiveness of VaPaMaMa in targeting key areas of cognitive development. Enhanced problem-solving and reasoning skills are foundational for academic success and critical thinking.

The convergence of quantitative data, classroom observations, and educator feedback provides robust evidence that the VaPaMaMa instructional media significantly enhances cognitive abilities in preschool-aged children more effectively than traditional educational methods. The following points summarize the comprehensive findings:

- Enhanced Cognitive Development: Statistically significant improvements in cognitive scores demonstrate the efficacy of VaPaMaMa in fostering essential cognitive skills.
- Improved Engagement and Social Skills: Increased engagement and better collaboration among peers indicate that VaPaMaMa supports

both individual and social aspects of learning.

- Practical Implementation: Educator feedback highlights the practicality and adaptability of VaPaMaMa, suggesting that it can be effectively incorporated into various educational settings without substantial additional resources.

The study presents compelling evidence that VaPaMaMa is a highly effective instructional tool for enhancing cognitive abilities in preschool-aged children. The significant quantitative improvements are corroborated by qualitative observations and positive educator feedback, illustrating the multifaceted benefits of integrating play-based, interactive learning environments in early childhood education. This holistic approach not only boosts cognitive skills but also promotes greater engagement and social interaction, laying a strong foundation for lifelong learning

Discussion

The results from this study provide strong evidence supporting the effectiveness of the Mathematics Playboard Variation (VaPaMaMa) in enhancing the cognitive abilities of preschool-aged children. The significant improvements observed in the experimental group, as opposed to the modest changes in the control group, suggest that the interactive and engaging nature of VaPaMaMa plays a crucial role in stimulating cognitive development. This finding is consistent with Vygotsky's sociocultural theory, which emphasizes the importance of interactive learning environments and tools that act as mediators in cognitive development.

The finding that emphasizes the importance of interactive learning environments and tools as mediators in cognitive development aligns with Vygotsky's sociocultural theory, which underscores the significance of social interactions in learning(Drew, 2019; Krish et al., 2012; Lewinn et al., 2020; Liu et al., 2024). Vygotsky proposed that cognitive development is greatly influenced by social interactions and the use of tools or technologies as cognitive aids. The research on co-viewing of live video streaming (LVS) highlights the positive effects of learner-learner interaction on attention allocation, learning performance, efficiency, and metacognition(Hampel & Stickler, 2012). Additionally, studies on computer-supported learning environments emphasize the necessity of interaction to facilitate effective learning, particularly through social presence and interpersonal interactions. The use of videoconferencing in language learning further demonstrates how interaction with experts, peers, and technology mediates the learning process, supporting Vygotsky's theory.

The large effect size observed (Cohen's d = 1.21) not only demonstrates the statistical significance of the results but also underscores the practical significance of incorporating such innovative tools in early childhood education settings. This aligns with information processing theories that advocate for instructional methods enhancing encoding, storage, and retrieval of information, which VaPaMaMa appears to facilitate effectively.

Alignment with Existing Literature

Play-based learning environments have been extensively studied, with research indicating that children benefit significantly from educational settings that integrate play into the learning process (Hori & Fujii, 2021)(Hori & Fujii, 2021). Siritheeratharadol et al. (2023) emphasize that active engagement in learning,

particularly through play, enhances children's learning outcomes(Siritheeratharadol et al., 2023). The VaPaMaMa's design aligns with this concept by combining play and learning through visually engaging elements, catering to the developmental needs of young learners, as supported by Piaget's cognitive development theory.

Moreover, recent studies in cognitive science and educational neuroscience have highlighted the effectiveness of play-based learning in early childhood education (Lamrani & Abdelwahed, 2020). This approach resonates with children's natural inclination towards play and has shown promise in improving skills and knowledge acquisition. Novaliendry et al. (2022) further confirm the suitability of interactive media, such as augmented reality, for early childhood learning, suggesting its potential implementation in educational settings like schools and kindergartens.

The importance of hands-on teaching methods for knowledge acquisition is underscored by (Vogt et al., 2022). This emphasizes the significance of practical education, which aligns with the interactive and manipulable elements present in play-based learning environments like VaPaMaMa. By engaging children actively in the learning process, educational tools that incorporate play can enhance learning outcomes significantly. The synthesis of these references supports the idea that play-based learning environments, such as the VaPaMaMa design, are beneficial for children's educational development. By integrating play with learning activities that cater to children's natural inclinations, educators can create engaging and effective learning experiences that promote better learning outcomes.

The positive outcomes of this study highlight the potential of integrating innovative play-based instructional media like the Mathematics Playboard Variation (VaPaMaMa) in early childhood education to enhance cognitive development. By aligning instructional strategies with the natural play instincts of children and the theoretical underpinnings of cognitive development, educators can significantly enhance learning outcomes. This research not only contributes to the academic field but also offers practical insights for educators seeking to optimize educational practices for young learners.

Implications for Early Childhood Education

The implications of this research are manifold. First, the study suggests that early childhood educational settings can benefit from incorporating more play-based, mathematically-focused instructional media like VaPaMaMa. Such tools not only enhance cognitive skills but also foster a positive attitude towards learning and mathematics at a young age, potentially paving the way for better academic outcomes in later schooling years.

Moreover, the observed improvements in social interactions and collaborative skills among the experimental group participants suggest that play-based instructional tools can also support social and emotional learning. This is crucial in early childhood education, where developing interpersonal skills is as important as cognitive skills.

Conclusion

The Mathematics Playboard Variation (VaPaMaMa) has demonstrated significant potential in enhancing the cognitive abilities of preschool-aged children, as evidenced by the findings of this study. Through the use of a quasi-experimental

design, this research provided empirical support for the effectiveness of VaPaMaMa, an innovative instructional media that merges mathematical learning with playful engagement. The experimental group, which interacted with VaPaMaMa, showed marked improvements in cognitive abilities compared to the control group, which continued with traditional educational methods.

The results from this study affirm the theories of cognitive development by Piaget and Vygotsky, illustrating how well-designed instructional tools that incorporate elements of play can significantly influence cognitive growth. Specifically, VaPaMaMa facilitated an engaging learning environment that not only enhanced mathematical skills but also improved memory, problem-solving abilities, and critical thinking among young learners.

Suggestion

This research suggests that integrating play-based educational tools like VaPaMaMa into early childhood curricula can greatly benefit cognitive development. This aligns with contemporary educational priorities that emphasize the importance of early cognitive foundations for later academic success. Additionally, the positive feedback from educators regarding the usability and effectiveness of VaPaMaMa underscores its potential as a valuable addition to educational settings, fostering an enjoyable and stimulating learning environment.

Limitation

While the findings are promising, there are several limitations to this study. The sample size was relatively small and confined to a specific geographic area, which may limit the generalizability of the results. Future research could involve a larger and more diverse sample to validate these findings further. Additionally, the study was conducted over a short period (eight weeks), and the long-term effects of using VaPaMaMa on cognitive and social skills remain unknown. Longitudinal studies could help determine the sustainability of the cognitive benefits observed and whether they translate into long-term academic success

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