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Effect of STEM Picture Book (Shape by Shape) and Play-Game Interventions on Early Mathematics Achievement among Preschool Children in Kota Kinabalu, Sabah, Malaysia

Journal of Electrical Systems

Abstract: - In the field of early childhood education, there has been a lot of interest in preparing young children for mathematics instruction. The purpose of this study was to identify and compare the effects of the STEM Picture Book (Shape by Shape) and Play-Game Intervention using Augmented Reality on Early Mathematics Performance. The instrument used in this research was the Early Mathematics Achievement Test (TEMA) which was adapted from Ginsburg and Baroody (2003) and, Doig and Ompok (2010), based on the National Standard Preschool Curriculum Malaysia 2017. In this study, 50 preschoolers from national preschools in Kota Kinabalu, Sabah, participated in a quantitative quasi-experimental design. Before the intervention, the results of the independent t-test revealed no significant difference in early mathematics achievement between the control and treatment groups (p=.20). However, the paired t-tests demonstrated significant improvements in early mathematics achievement between the control group (p=.00) and treatment group (p=.00) before and after the intervention. The independent t-test showed a significant difference in early Mathematics achievement between the control and treatment groups (p=.01) after the intervention. Overall, the findings indicate that the STEM Picture Book (Shape by Shape) and Play-Game Intervention significantly enhance early Mathematics achievement compared to conventional teaching methods. These findings provide educators with practical guidance on how to incorporate cutting-edge technology, such augmented reality, which has the potential to create an immersive and dynamic learning environment.

Keywords— Play-Game, picture book, Shape by Shape, Early Mathematics Achievement, Preschool children, Augmented Reality.

I. Introduction

Children aged 4-6 years, commonly referred to as preschoolers, are in a critical developmental phase where they are prepared for formal education. This period is marked by heightened sensitivity to environmental stimuli, making it an ideal time for foundational learning that fosters spiritual, emotional, and cognitive growth. According to Burchinal et al. (2022), Early Childhood Education (ECE) settings, encompassing educational environments for children from birth to six years, prior to formal schooling, hold immense potential to profoundly influence children's development. These settings provide opportunities for children to excel across all developmental domains, including social, emotional, cognitive, language and physical growth.

For future success, a solid mathematical foundation prior to formal schooling is essential (Jordan, 2010; Sarama et al., 2012). A solid foundation in mathematics is a major factor in determining performance in elementary school, secondary school, and even higher education (Duncan et al., 2007). Early education is also necessary for the development of mathematical abilities needed later in life (Linder et al., 2011; Hunting et al., 2012). Influential research, such as the Perry Preschool and Abecedarian initiatives, have shown that underprivileged children can benefit in the long run from higher rates of finishing higher education, higher incomes, and lower crime rates (Heckman et al., 2000). Given the importance of mathematics education for the future, early mathematics intervention programs must be prioritized. According to Presser et al. (2015), increasing attention from educators, researchers, and policymakers on the quality of early mathematics education is due to the growing knowledge of children's early development.

1.1 Problem Statement

Despite significant investments in advancing education in Malaysia, students' Mathematics performance continues to decline, as reflected by a notable drop in average scores in TIMSS and PISA (Mullis et al., 2012; Walker, 2011; De la Fuente & Doménech, 2024). While Malaysia aspires to improve its performance in international assessments such as PISA and TIMSS, its results have been underwhelming. In 2019, 16.87% of the students received a grade E in Mathematics (Ministry of Education Malaysia, MOE, 2019), and as of 2023, 269,332

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students were reported to lack mastery of foundational 3M skills; reading, writing and arithmetic (Nordin, 2023). An early emphasis on Science, Technology, Engineering, and Mathematics (STEM) education at the preschool level is essential to cultivate interest in these subjects (Mazana et al., 2019).

Children, who are natural mathematical thinkers, require innovative teaching approaches to enhance their performance. A number of factors contribute to Malaysian pupils' poor math performance, including a lack of focus on efficient teaching and learning strategies and few opportunities for kids to develop a solid understanding of the subject (Turan & Smedt, 2022; Outhwaite et al., 2024; Gifford, 2004; Otsuka & Jay, 2016). Teachers often overlook play-based approaches, which are crucial for early childhood development. The National Preschool Standard Curriculum (NPSC) holds promise for reform through a constructivist approach (Ministry of Education Malaysia, 2017). Developing children's mathematical thinking skills from the early stages of schooling is crucial and can be achieved through effective pedagogical practices (Ompok, 2021). Previous research also suggests that early intervention can help improve children's achievement (Doig & Ompok, 2010; Ompok et al., 2021a; Ompok et al., 2021b; Ompok & Bacotang, 2019; Ompok & Emison, 2021). Noraidi et al. (2024) found that the use of concrete materials sourced from the natural environment significantly increased children's interest in early mathematics learning. However, there is a need to enhance teachers' knowledge and skills in effective Mathematics teaching by using technology. Further research is required to assess the effect of incorporating technology on early Mathematics achievement.

STEM education is widely recognised for promoting collaboration and knowledge-sharing among educators and students which enhances their learning opportunities. Critical thinking, creativity, and teamwork are STEM skills that are crucial in today's workforce. These abilities help children develop 21st-century skills like literacy and communication, enabling them to take on real-world problems and come up with creative solutions. STEM seeks to increase students' interest in science, technology, engineering, and mathematics by fusing these areas through interesting and useful activities.

This developmental "golden age"(ages 4-6) is crucial for children’s development, as it lays the groundwork for future learning and skill acquisition. The integration of information technology as a learning tool has proven to enhance educational outcomes, particularly in early childhood settings, where it supports both students and educators. Technology has revolutionized the learning process by enabling access to resources anytime and anywhere. In education, the impact of information technology is increasingly significant, leading to notable improvements in teaching and learning. The advancements in information and communication technology (ICT) have made it easier to access educational content through computers, smartphones and the Internet. Augmented Reality (AR) is regarded as one of the most promising technologies for K–12 and higher education (Ibáñez & Delgado-Kloos, 2018).

1.2 Research Objectives

(i) To compare the mean scores of early Mathematics achievement between the control group and treatment group before the implementation of teaching.
(ii) To identify differences in the mean scores of early Mathematics achievement among preschool children in the control group before and after the implementation of teaching.
(iii) To identify differences in the mean scores of early Mathematics achievement among preschool children in the treatment group before and after the implementation of teaching.
(iv) To compare the mean scores of early Mathematics achievement between the control group and treatment group after the implementation of teaching.

1.3 Research Questions

(i) Is there a significant difference in the mean scores of early Mathematics achievement between the control group and treatment group before the implementation of teaching?
(ii) Is there a significant difference in the mean scores of early Mathematics achievement among preschool children in the control group before and after the implementation of teaching?
(iii) Is there a significant difference in the mean scores of early Mathematics achievement among preschool children in the treatment group before and after the implementation of teaching?
(iv) Is there a significant difference in the mean scores of early Mathematics achievement between the control group and treatment group after the implementation of teaching?

1.4 Research Hypotheses

Ho1 There is no significant difference in the mean scores of early Mathematics achievement between the control group and treatment group before the implementation of teaching.

Ho2 There is no significant difference in the mean scores of early Mathematics achievement among preschool children in the control group before and after the implementation of teaching.

Ho3 There is no significant difference in the mean scores of early Mathematics achievement among preschool children in the treatment group before and after the implementation of teaching.

Ho4 There is no significant difference in the mean scores of early Mathematics achievement between the control group and treatment group after the implementation of teaching.

II. LITERATURE REVIEW

2.1 Theory Related to Mathematical Thinking

"Number learning begins with arithmetic operations, which are the most fundamental" (Chin, 2013). The focus at this stage starts with the skills of recognizing, counting, and calculating numbers in smaller quantities (Griffin et al., 1994). Baroody (1987) emphasized that early mathematics learning among children is based on a gradual developmental concept that involves discovery and constructing a deeper understanding of numbers and arithmetic concepts. Mastery of basic arithmetic is essential to enable children to use numbers freely for various operations (such as division and multiplication) without constantly relying on counting (Chin, 2013).

2.2 Traditional Method

According to Bredekamp and Copple (1997), worksheets are typically preferred by teachers. However, this approach does not align with Developmentally Appropriate Practices (DAP) for children. Changing long-standing teaching practices is difficult without empirical evidence. Baroody (2006) emphasized that traditional methods, which largely rely on worksheets, act as a barrier to the acquisition of mathematical knowledge. This opinion is supported by Davis et al. (1990), who argued that show-and-tell activities and rote drills have limited usefulness from a constructivist perspective. According to Hong (1999), traditional mathematical activities such as counting objects, writing numbers, and using worksheets may be too abstract and less meaningful for children. Based on findings from Grossman (1996) and Burts et al. (1992), as well as statements by Ransom and Manning (2013) and Hong (1999), worksheets are considered less aligned with DAP, even though they remain a preferred choice among teachers because they fail to address children's socio-emotional aspects. Quality mathematics teaching should be challenging, enjoyable and free from pressure for children.

2.3 Previous Studies Related to the Use of Technology in Early Childhood Education

Learning is a comprehensive system comprising various interconnected components aimed at creating optimal conditions for achieving learning objectives. Effective learning extends beyond meeting curriculum requirements. It also involves human interaction, materials, and the use of suitable techniques and tools. The quality of the learning process is essential for producing competent graduates, which underscores the importance of focusing on creating high-quality learning environments. Modern learning media, designed to capture students' attention, are crucial in this process. Technology-based learning resources can effectively interest young children if they are well-designed.

According to Hsu et al. (2017), technologies like AR and virtual reality (VR) can give students immersive experiences and contextual learning opportunities that enhance learning. However, research on technology education for young children aged 3 to 8 years has received less attention in the past than studies conducted on other age groups ((Albayrak & Yilmaz. 2022). Access to high-quality early learning is linked to greater academic attainment across the lifespan. Although technology's role in early childhood education is expanding, there aren't enough resources to make sure it's being used as efficiently as possible (Payne et al., 2024).

Research by Razi and Jamiat (2023) analysed ten studies on the benefits of AR technology for early childhood from 2020 to 2022. Consequently, Akçayır and Akçayır (2017) suggested broadening AR research to include different demographics, such as ECE. As interest and studies on AR in early education grow, it is anticipated that educators will gain additional training and resources to enhance their skills in incorporating digital technology into their teaching practices. Furthermore, the findings of Zourmpakis et al. (2022) indicate that students are generally more engaged and exhibit better performance when their learning experiences are integrated with digital technology.

Schladant et al. (2022) also looked at the effectiveness of assistive technology (AT). In addition to not receiving the full benefits of inclusive preschool education, many disabled children lack access to assistive technology. The study used quantitative techniques such as classroom observations, early literacy evaluations, and pre- and post-surveys. The findings showed that children's use of AT and early reading abilities rose dramatically from before to after the intervention, and that teachers' knowledge, positive perceptions, and use of AT increased as well.

Wang et al. (2024) examine how children in China are affected by AR technology used in STEM preschooler modules for educational activities. Results show that the Augmented Reality Integrated STEM Preschooler (ARISP) module greatly boosts kids' motivation and involvement in educational activities. The interactive features of AR technology improve problem-solving abilities and provide a deeper comprehension of STEM ideas. The integration of advanced technology with conventional teaching methods in the ARISP module shows great promise for improving early childhood education.

2.4 Early Mathematics Achievement

According to Mix et al. (2002), the stages of mathematical thinking are divided into three phases. The first phase is the **pre-counting phase**. The second phase is the **counting phase**, and the third phase is the **written number phase**. According to Ginsburg and Baroody (2003), children in the early pre-thinking phase initially do not use words to think about a set and how changes occur, but they may use mental images. Children can accurately count sets of objects, build a basic understanding of numbers, and perform simple addition and subtraction operations even before entering school. Children around three and a half years old can remember and reproduce sets of objects from one to four without counting. At ages three and a half to five, they can show the sum or difference when a small number of items is added or subtracted from previously seen objects. Furthermore, they can solve simple addition and subtraction problems non-verbally before successfully solving story problems or symbolic tasks such as 2 + 1 =? In the counting phase, Mix et al. (2002) state that children can verbally express numbers while counting in words.

III. METHODOLOGY

3.1 Research Design

This study is a quasi-experimental design involving children from two kindergartens in Kota Kinabalu, Sabah, to examine the effects of the STEM Picture Books and Play-Game Intervention on early Mathematics achievement. The study includes two groups: a control group using conventional teaching methods and a treatment group using the Home-based STEM Picture Books and Play-Game Intervention. After eight weeks of instruction, both groups completed pre-and post-tests to evaluate the effects of the teaching. The quasi-experimental design was chosen because the respondents could not be randomly assigned due to school schedule constraints, allowing for a comparison of the mean achievement scores between the control and treatment groups (Darusalam & Hussin, 2016). In summary, this study uses a quasi-experimental design with pre- and post-tests as shown in Table 1.

Table 1: Quasi-Experimental Design

Pre	**Teaching Method**	**Post**
Control Group	Conventional	Control Group
Treatment Group	STEM Picture Books and Play-Game Intervention	Treatment Group

3.2 Measurement Tools

The instrument used in this research was the Early Mathematics Achievement Test (TEMA) which was adapted from Ginsburg and Baroody (2003) and, Doig and Ompok (2010), based on the National Standard Preschool Curriculum Malaysia 2017 (MOE, 2017).

3.3 Instrument Reliability

Reliability refers to the consistency of an instrument in measuring a task (Wiersma, 1995). The reliability analysis of the instrument indicated high reliability based on Cronbach's Alpha scale (Pallant, 2001). The researchers allocated approximately 30 minutes to administer the test to the children, ensuring they clearly understood the questions. To minimize distractions, the test was conducted in a closed room. The reliability analysis of the instrument showed high Cronbach's Alpha values: pilot study α=0.80. Table 2 presents the results of the reliability analysis for the instrument used during the pilot study.

Table 2: Results of the reliability analysis for the instrument

Test	Question Number	Number of Items	Alpha Cronbach α	Reliability Level
Pilot Test	1 to 28	28	0.8	High

3.4 The intervention

STEM Picture Book Shape by Shape and Play-Game Intervention

The importance of STEM education in early childhood, especially in the context of sustainable development, was examined in the study by Campbell and Speldewinde (2022). They believed that promoting an awareness of the natural world and children's involvement in a sustainable future. It seems that incorporating STEM into the curriculum for young children and providing professional development for teachers is a potential way to get kids ready for the challenges of the twenty-first century.

Shape by Shape is a preschool STEM picture book, which was developed by an early childhood expert in Malaysia. This book introduces Young Engineers: Shape by Shape not only to recognize simple shapes such as triangles, rectangles and squares but also to acquire the necessary knowledge and skills in numbers and engineering. The app is an interesting and entertaining teaching tool that teaches kids about shapes. It has a learning interface and two mini-games. The immersive learning interface effectively helps kids understand the notion of shapes by fusing engaging images and sound. Children are challenged to solve puzzles by arranging shapes into very complicated patterns, like a house, in one of the mini-games, which focuses on strengthening their knowledge and recall of shapes.

3.5 Data Analysis Methods

For data analysis, inferential statistics including independent t-tests and paired t-tests, were used.

IV. Result

H_{01} There is no significant difference in the mean scores of early Mathematics achievement between the control group and treatment group before the implementation of teaching.

Table 3 presents the results of the independent t-test. Levene's test for homogeneity of variance indicated that $p > .05$, therefore the t-test results are based on the assumption of equal variances. The analysis showed $t(36) = -0.50$, $p > .05$. As a result, the null hypothesis was not rejected. This means there was no significant difference in the early mathematics achievement of preschool children between the control group (M = 40.20, SD = 6.20) and the treatment group (M = 42.25, SD = 6.70) before the implementation of the teaching.

Table 3: Independent t-Test Analysis for Mean Early Mathematics Achievement Scores Before (Pre-Test) the Implementation of Teaching Between the Control Group and the Treatment Group

Groups	Mean	Standard deviation	Levene's Test Sig.	t-value	Df	Sig.level
Control Group	40.20	6.20	.74	-.50	36	.28
Treatment Group	42.25	6.70				

H_{02} There is no significant difference in the mean scores of early Mathematics achievement among preschool children in the control group before and after the implementation of teaching.

Table 4 presents the results of the paired t-test. The analysis revealed $t(36) = -0.12$, $p < .05$. Therefore, the null hypothesis is rejected. This indicates that there was a significant difference in the early mathematics achievement of preschool children in the control group before (M = 40.20, SD = 7.80) and after (M = 76.55, SD = 8.55) the implementation of teaching.

Table 4: Paired t-Test Analysis for Mean Achievement Scores of Preschool Children in the Control Group Before (Pre-Test) and After (Post-Test) the Implementation of Teaching

Control Group	Mean	Standard deviation	t-value	Df	Sig.level
Pre-Test	40.20	7.80	-.12	36	.00
Post-Test	76.55	8.55			

H_{o3} There is no significant difference in the mean scores of early Mathematics achievement among preschool children in the treatment group before and after the implementation of teaching.

Table 5 presents the results of the paired t-test. The analysis revealed $t(36) = -0.12$, $p < .05$. Therefore, the null hypothesis is rejected. This indicates that there was a significant difference in the early mathematics achievement of preschool children in the treatment group before (M = 42.25, SD = 7.26) and after (M = 82.40, SD = 9.60) the implementation of teaching.

Table 5: Paired t-Test Analysis for Mean Achievement Scores of Preschool Children in the Treatment Group Before (Pre-Test) and After (Post-Test) the Implementation of Teaching

Treatment Group	Mean	Standard deviation	t-value	Df	Sig.level
Pre-Test	42.25	7.26	-.12	36	.001
Post-Test	82.00	9.60			

H_{o4} There is no significant difference in the mean scores of early Mathematics achievement between the control group and treatment group after the implementation of teaching.

Table 6 presents the results of the independent t-test. Levene's test for homogeneity of variance showed that $p > .05$, so the t-test results are based on the assumption of equal variances. The analysis revealed $t(36) = -2.27$, $p < .05$. Therefore, the null hypothesis is rejected. This suggests that there was a significant difference in the early mathematics achievement of preschool children between the control group (M = 71.00, SD = 8.20) and the treatment group (M = 82.40, SD = 8.08) after the implementation of teaching.

Table 6: Independent t-Test Analysis for Mean Early Mathematics Achievement Scores After (Post-Test) the Implementation of Teaching Between the Control Group and Treatment Group

Groups	Mean	Standard deviation	Levene's Test Sig.	t-value	df	Sig.level
Control group	71.00	8.20	.64	-2.27	36	.02
Treatment group	82.40	8.08				

V. Discussion And Conclusion

The results of the independent t-test show that before the implementation of conventional teaching and the STEM Picture Book (Shape by Shape) and Play-Game Intervention, there was no significant difference in the early mathematics achievement scores between the control group and treatment group. This indicates that both groups had similar levels of mathematics skills before the treatment sessions. This similarity may be attributed to the use of the same learning standards in the National Preschool Curriculum and similar teaching methods before this study was conducted. After the intervention, the treatment group showed a significant difference in the mean early mathematics achievement scores compared to the treatment group.

The use of technology helps children increase their performance as previous study done by Schladant et al. (2022) and Wang et al. (2024). This study recommends that early childhood teachers incorporate technology into their teaching practices as an innovative and engaging tool for future educational endeavors as suggested by Zourmpakis et al. (2022) and Payne et al. (2024).

This study had limitations despite its contributions, including a limited sample size that would have affected how broadly the results could be applied. Future studies should use bigger, more varied sample sizes and take into account other variables that affect preschoolers' development, such as parental education and family income. Future research directions suggested by this study include evaluating the efficacy of technology in teaching and learning, comparing it to traditional learning, and using it to help students develop their critical thinking and problem-solving skills.

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