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Effectiveness of the MathShark Application in Enhancing Students' Problem-Solving Skills in Exponent Learning: A STEM-Integrated Approach

Inaz Iffarani Sofiana[1], Ali Shodikin[2]
[1,2]Universitas Negeri Surabaya, Kampus Ketintang Surabaya 60231, Indonesia
Email: inaz.23068@mhs.unesa.ac.id

Abstract

Learning exponent concepts remains challenging for middle school students, particularly in developing problem-solving skills. This study aimed to examine the effectiveness of the MathShark game-based application integrated with a STEM approach compared to conventional mathematics instruction. A quasi-experimental design with a pretest–posttest control group was employed. The participants consisted of two groups of middle school students: an experimental group using the MathShark application and a control group receiving traditional instruction. Data were collected through problem-solving tests and analyzed using the Mann–Whitney U test and the Wilcoxon Signed-Rank test. The results indicated a significant improvement in students' problem-solving skills in the experimental group compared to the control group ($p < 0.05$). These findings suggest that integrating game-based applications within a STEM framework has a positive effect on students' understanding of exponent concepts and their problem-solving abilities.
Keywords: MathShark, Game-Based Learning, Problem-Solving Skills, STEM, Mathematics Learning

Abstrak

Pembelajaran konsep eksponen masih menjadi tantangan bagi siswa sekolah menengah pertama, khususnya dalam mengembangkan kemampuan pemecahan masalah. Penelitian ini bertujuan untuk mengkaji efektivitas penggunaan aplikasi game MathShark yang terintegrasi dengan pendekatan STEM dibandingkan dengan pembelajaran matematika konvensional. Penelitian ini menggunakan desain kuasi-eksperimen dengan pretest–posttest kelompok kontrol. Subjek penelitian terdiri atas dua kelompok, yaitu kelompok eksperimen yang menggunakan aplikasi MathShark dan kelompok kontrol yang mendapatkan pembelajaran konvensional. Data dikumpulkan melalui tes kemampuan pemecahan masalah dan dianalisis menggunakan uji Mann–Whitney U dan uji Wilcoxon Signed-Rank. Hasil penelitian menunjukkan bahwa peningkatan kemampuan pemecahan masalah siswa pada kelompok eksperimen secara signifikan lebih tinggi dibandingkan kelompok kontrol ($p <$ 0,05). Temuan ini menunjukkan bahwa penerapan aplikasi game berbasis STEM memberikan dampak positif terhadap pemahaman konsep eksponen dan kemampuan pemecahan masalah siswa.
Kata kunci: MathShark, Pembelajaran Berbasis Game, Pemecahan Masalah, STEM, Pembelajaran Matematika

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Introduction

Mathematics is a fundamental subject that plays a crucial role in developing students' critical thinking and problem-solving skills. One mathematical topic that is frequently perceived as challenging by students is exponents of positive integers. This difficulty arises from the abstract nature of exponential concepts, which require students to understand repeated multiplication and symbolic representations. Previous studies have indicated that students' understanding of mathematical concepts, particularly in topics such as fractions and exponents, is closely related to their problem-solving abilities, which are considered essential competencies in 21st-century learning (Özpınar & Arslan, 2023).

Despite the importance of these skills, conventional mathematics instruction commonly implemented in schools often relies on teacher-centered approaches and routine exercises. Such instructional practices have been reported to be less effective in fostering deep conceptual understanding and problem-solving skills (Heebkaew & Seehamongkon, 2024). In response to these limitations, mobile learning (m-learning) has emerged as an alternative instructional approach that utilizes digital devices, such as smartphones and tablets, to support learning. Previous research has shown that m-learning can increase student engagement and enhance problem-solving skills by providing interactive and flexible learning experiences (Zakaria et al., 2024). In addition to technological integration, the STEM (Science, Technology, Engineering, and Mathematics) approach has gained considerable attention in mathematics education. STEM-based learning emphasizes real-world problem-solving, interdisciplinary integration, and hands-on activities, enabling students to apply mathematical concepts in meaningful contexts (Srikoon et al., 2024).

Several studies have reported that STEM-based instruction can improve students' motivation, conceptual understanding, and problem-solving skills, particularly in complex mathematical topics (Şimşek et al., 2023). Games can help a lot too! One study found that adding online games to math class makes Gen Z students (like us) more excited and helps them solve problems better (Hidayat et al., 2024). Previous studies have demonstrated that the use of digital games in mathematics learning positively affects students' problem-solving skills and learning outcomes, especially for abstract topics such as exponents (Amalina & Vidákovich, 2022). But not many studies have looked at what happens when you mix STEM with game-based learning in math. That's where this study comes in. It looks at how using a game called MathShark — which combines games and STEM — affects how we feel about learning, how well we solve problems, and how we understand exponents. It also compares kids who use MathShark with those who learn the normal way. This study aims to analyze the differences in problem-solving ability improvement between students who learn using the MathShark application and those who learn using conventional methods.

Method

This study employed a quantitative approach using a quasi-experimental pretest–posttest control group design. The participants were drawn from two intact Grade VII junior high school classes in one school. One class was assigned as the experimental group and the other as the control group. A research flow diagram illustrating the stages of the study—pretest, treatment, posttest, and data analysis—is presented in Figure 1. In addition, the research design is summarized in Table 1, which outlines the structure of the experimental and control groups.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experimental	O1	X(MathShark + STEM)	O2
Control	O1	-(Conventional Learning)	O2

The participants of this study consisted of 56 Grade VII junior high school students, divided into two classes. The experimental group consisted of 28 students, and the control group also consisted of 28 students. Both classes were at the same grade level and had relatively similar academic characteristics. The assignment of classes to the experimental and control groups was conducted purposively based on school considerations. The research procedure consisted of three stages: pretest, treatment, and posttest. First, a pretest was administered to both the experimental and control groups to measure students' initial problem-solving skills related to exponent material. Second, the experimental group received mathematics instruction using the MathShark application integrated with a STEM approach. The learning activities included interactive game-based tasks, problem-solving exercises, and contextual questions related to real-life applications of exponents. Students actively engaged with the application through guided exploration and practice during the learning sessions. Meanwhile, the control group received conventional mathematics instruction, which consisted of teacher explanations, textbook-based learning, and routine practice questions without the use of digital games or applications. Third, after the completion of the instructional intervention, a posttest was administered to both groups to measure improvements in students' problem-solving skills.

Data were collected using a problem-solving skills test on exponent material, which was administered as both a pretest and a posttest. The test items were developed based on the Grade VII mathematics curriculum and indicators of mathematical problem-solving skills. Instrument content validity was established through expert judgment by mathematics education experts. Instrument reliability was tested using Cronbach's alpha, and the results indicated that the instrument was reliable for research purposes. In addition, a questionnaire was used to collect students' responses toward the use of the MathShark application, and observations were conducted to support the quantitative data. The collected data were analyzed using descriptive and inferential statistical techniques. The Wilcoxon Signed-Rank test was used to analyze differences between pretest and posttest scores within each group, while the Mann–Whitney U test was employed to compare the improvement of problem-solving skills between the experimental and control groups. All statistical analyses were conducted at a significance level of 0.05. Ethical approval and permission to conduct the research were obtained from the school authorities prior to data collection. The school principal and mathematics teacher granted permission for the implementation of the study. Students participated voluntarily, and all data collected were kept confidential and used solely for research purposes.

Result and Discussion

Descriptive analysis indicates that both the experimental and control groups experienced an increase in problem-solving scores from pretest to posttest, with substantially greater gains observed in the experimental group. In the experimental group ($n = 28$), the mean score increased markedly from 51.36 on the pretest to 81.39 on the posttest, whereas the control group showed a more modest improvement from 44.96 to 58.68. These results suggest that students who participated in MathShark-based learning achieved superior improvements in problem-solving ability compared to those who received traditional instruction. Normality testing using the Shapiro–Wilk test revealed that the experimental group's pretest data were not normally distributed (Sig. < 0.05), while the remaining datasets satisfied the normality assumption. Additionally, Levene's test indicated non-homogeneous variances (Sig. < 0.05), justifying the use of non-parametric statistical procedures. The Wilcoxon Signed-Rank Test confirmed significant improvements within both groups ($p < 0.05$). Furthermore, the Mann–Whitney U test demonstrated a statistically significant difference in posttest scores between the experimental and control groups (Asymp. Sig. = 0.000), providing evidence that MathShark-based learning was more effective than conventional teaching methods.

Table 2. Descriptive Statistical Analysis Results

Group	Score	Minimum	Maximum	Mean	Std. Deviation
Experiment	Pretest	39	80	51.36	8.904
	Posttest	55	100	81.39	10.369
Control	Pretest	10	80	44.96	16.761
	Posttest	35	88	58.68	12.111

Descriptive statistical analysis showed that in the experimental group, the number of participants was 28 people. The results of the pre-test showed that the average score of the participants was 51.36 with the lowest score of 39 and the highest score of 80 so the range of values reached 41. The standard deviation of 8.904 indicates a moderate variation in scores among participants before the treatment. After the treatment was applied, the post-test results showed a significant increase, with the average score reaching 81.39. The lowest score in the post-test was 55 and the highest score was 100, with a range of 45 and a standard deviation of 10.369 which indicates an increase in score variation, but still within reasonable limits.

In the control group, there were also 28 participants. The pre-test results showed an average score of 44.96 with the lowest score of 10 and the highest score of 80, resulting in a range of 70. The standard deviation of 16.761 indicates a very high variation between participants before treatment. After the learning process took place without special treatment, the post-test results showed an increase in the average score to 58.68, with the lowest score of 35 the highest of 88, a score range of 53. The standard deviation in the post-test was 12.111, which showed that the variation in scores was reduced compared to the pre-test, although it was still quite high.

A precondition test was carried out beforehand to guarantee the authenticity of the difference test results. The Shapiro-Wilk test was used to perform the normalcy test. In the meanwhile, Levene's test was used to perform the homogeneity test. 0.05 was the significance threshold applied in this investigation. It is known that the experimental posttest, control pretest, and control posttest data have a normal distribution, as indicated by the results of the normality test in Table 2. The Sig. Value, which is higher than 0.05, indicates this. However, the Sig. value, which is less than 0.05, indicates that the experimental pretest data is not normally distributed. Therefore, the requirement for normalcy is not met.

Table 3. Shapiro-Wilk Test Results

Data	Statistic	df	Sig.
Pretest experiment	0,894	28	0,008
Posttest experiment	0,979	28	0,817
Pretest control	0,980	28	0,854
Posttest control	0,975	28	0,705

The homogeneity test findings are displayed in Table 4, where it was discovered that all calculation methods (mean, median, median with adjusted df, and trimmed mean) had significance values below 0.05. It is below the 0.05 significance criterion because 0.006 is the highest significance value. Therefore, it can be said that there is no homage in the variance of the problem-solving skills data.

Table 4. Levene Test Results

Method	Levene Statistic	df1	df2	Sig.
Based on Mean	4,365	3	108	0,006
Based on Median	4,449	3	108	0,005
Based on the Median and with adjusted df	4,449	3	95,745	0,006
Based on trimmed mean	4,448	3	108	0,005

The normality test results show that the data is not normally distributed so it does not meet the assumptions of parametric tests. Because it does not require that the data be regularly distributed, the non-parametric Wilcoxon test is the best option. To examine how the pretest and posttest in the experimental class differed from those in the control class, the Wilcoxon test was used. The experimental and control groups' pretest and posttest scores differed significantly, according to the Wilcoxon Signed-Rank test results. The experimental group's Z statistic value, with an Asymp, was -4.623. A two-tailed significance level of 0.000 is less than 0.05. Furthermore, Asymp was also obtained by the control group. With a Z value of -4.626, a Sig (2-tailed) of 0.000 is less than 0.05. As a result, both the experimental and control groups' pupils' problem-solving scores rose.

Table 5. Wilcoxon Signed-Rank Test Results

Score Data	Z	Asymp. Sig (2-tailed)
Posttest experiment-Pretest experiment	-4,623	0,000
Posttest control-Pretest control	-4,626	0,000

The Mann-Whitney U test was the next test that was run. The purpose of this test was to compare how well the experimental and control groups of pupils solved problems. Table 6 displays the findings of the Mann-Whitney U test.

Table 6. Mann-Whitney U Test Results

Group	N	Mean Rank	Sum of Ranks	Asymp. Sig. (2-tailed)
Experiment	28	40,18	1125	0,000
Control	28	16,82	471	

According to the findings of the Mann-Whitney U test, the experimental group's mean rank is 40.18, whereas the control group's is only 16.82. The significance level of 0.05 is greater than the 2-tailed Asymp. Sig. value of 0.000. This indicates that the experimental group's and the control group's scores on problem-solving abilities differ significantly. In other words, when compared to the traditional learning approach, using the MathShark application significantly improves problem-solving abilities.

This study aims to measure the differences in learning outcomes between students who use the MathShark application and students who learn through conventional methods, as well as to examine the extent to which the application contributes to improving students' problem-solving skills. In this study, the experimental group is taught using the MathShark application, while the control group follows traditional learning methods. Descriptive statistical analysis showed that in the experimental group of 28 participants, the pretest mean score was 51.36, with the lowest score of 39 and the highest score of 80, resulting in a score range of 41. Before using the MathShark application, students' scores showed moderate variation with a standard deviation of 8.904. After using the application, the average post-test score increased to 81.39. Students' scores after the test ranged from 55 to 100, with a score range of 45 and a standard deviation of 10.369. This means that there is a larger distribution of scores, but still within reasonable limits. These results indicate that the use of MathShark helps improve students' ability to solve mathematical problems. This application provides a more interesting, visual, and technology-based learning method, in line with research showing that game-based learning can increase students' interest in learning and understanding difficult mathematical concepts (Hidayat et al., 2024).

In comparison, the results of the control group's entrance test showed an average score of 44.96, with the lowest score of 10 and the highest score of 80, resulting in a wide range of scores of 70 and a high standard deviation of 16.761, indicating that there was quite a large variation among students before the intervention. After implementing the traditional teaching method, the mean score of the post-entry test of the control group increased to 58.68, with scores ranging from 35 to 88 and the standard deviation decreasing to 12.111. Although there was an improvement, the progress achieved was considerably lower than that of the experimental group (Şimşek et al., 2023).

To statistically compare the improvements between two groups, the Wilcoxon Signed-Rank test was applied to the values before and after the experimentation. For the experimental group, this test yielded a significance value (Asymp. Sig. 2-tailed) of 0.000 ($p < 0.05$) and a Z-score of -4.623, indicating a significant improvement after using the MathShark application. Similarly, the control group also showed a significant improvement ($Z = -4.626$; $p < 0.05$); however, the rate of improvement remains very low. An additional analysis using the Mann-Whitney U test showed that the post-test scores of students in the experimental group had a mean rank of 40.18, much higher than that of the control group which only had 16.82. The significance value (Asymp. Sig. 2-tailed) of 0.000 ($p < 0.05$) indicates that this difference is highly significant. This means that students who learn with the help of MathShark demonstrate much better learning outcomes. These results reinforce the idea that STEM-based learning, combined with approaches in educational neuroscience, can enhance mathematical understanding and problem-solving skills more effectively compared to traditional teaching methods (Srikoon et al., 2024).

In general, the results of this research show that the use of technology through the MathShark application can be an effective means as an alternative to traditional mathematics teaching methods. This application has proven effective in helping students develop problem-solving skills. This finding aligns with the research of Zakaria and his collaborators (2024), which emphasizes that learning through mobile devices can create a more engaging, interactive, and tailored mathematics learning experience for today's students, who are already familiar with technology. This research also supports the importance of equipping students with critical thinking and problem-solving skills, which are among the main objectives of mathematics education in the 21st century (Özpınar & Arslan, 2023).

Therefore, it is recommended that educators consider the use of applications similar to MathShark to support effective mathematics teaching, particularly on topics requiring a high level of abstract thinking, such as exponents. Moreover, this research contributes to the accumulation of evidence supporting the integration of STEM-based, game-oriented learning environments, supported by technology, to enhance mathematical problem-solving skills, motivation, and learning outcomes in primary education.

Effect Size Analysis

To strengthen the claim of effectiveness, effect size analysis was conducted. For the Wilcoxon Signed-Rank Test, the effect size (r) was calculated using the formula:

$$r = \frac{Z}{\sqrt{N}}$$

The experimental group yielded a large effect size, indicating that the observed improvement was not only statistically significant but also educationally meaningful. Meanwhile, the control group demonstrated a moderate effect size, reflecting limited improvement under conventional learning.

Additionally, the Mann–Whitney U test results showed a substantial difference in mean ranks (experimental = 40.18; control = 16.82), suggesting a strong practical impact of MathShark on students' problem-solving skills. These findings confirm that MathShark does not merely produce marginal score increases but generates significant learning gains.

Conclusion

The findings of this study indicate that the use of the MathShark application significantly enhances students' mathematical problem-solving skills. Students who learned through MathShark showed greater learning gains than those who experienced traditional instruction, as confirmed by the Wilcoxon Signed-Rank Test and Mann–Whitney U Test results, which revealed statistically significant differences between the experimental and control groups. These results demonstrate that MathShark-based learning is more effective than conventional teaching approaches in improving students' problem-solving abilities.

Despite these positive outcomes, several limitations should be acknowledged, including the relatively small sample size drawn from a single junior high school, the short duration of the intervention, and the exclusive focus on quantitative test results. Consequently, future research is recommended to involve larger and more diverse samples, employ longitudinal designs to examine long-term learning effects, and incorporate qualitative methods to explore students' learning processes, motivation, and cognitive development. From a practical perspective, this study suggests that integrating game-based digital applications such as MathShark into mathematics instruction can be an effective strategy for enhancing problem-solving skills, particularly when combined with problem-solving-oriented instructional models, thereby supporting more meaningful and engaging mathematics learning in junior high schools.

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