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Enhancing Student Interest in Mathematics through Game-Based Learning: Identifying Challenges and Evaluating the Effectiveness of Educational Innovation

(Peningkatan Minat Pelajar dalam Matematik melalui Pembelajaran Berasaskan Permainan: Mengenalpasti Cabaran dan Menilai Keberkesanan Inovasi Pendidikan)

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ABSTRACT

This study focuses on the challenges of teaching mathematics among students in Southeast Asia, particularly in Malaysia, Indonesia and Thailand, where many students struggle with abstract concepts and perceive the subject as irrelevant to their daily lives. The objectives of this research are to identify specific challenges in mathematics learning, develop a game based learning module integrating fundamental mathematical concepts such as algebra, statistics, probability and linear equations and evaluating the module's effectiveness in enhancing students' interest and performance in mathematics. A quantitative methodology was employed, involving pre- and post-tests to measure student achievement improvements and perception surveys to evaluate students' engagement, practicality and satisfaction with the implemented learning module. The results revealed a significant improvement in students' mathematical performance post-intervention, with the majority transitioning from lower to higher proficiency levels. The impact of this study highlights the potential of game-based learning as an effective educational innovation capable of increasing motivation, conceptual understanding and addressing major challenges in mathematics education. These findings support the broader integration of innovative technology-driven learning approaches within educational systems.

Keywords: Game-based learning, Mathematics education, Student engagement, Educational innovation, Southeast Asia

ABSTRAK

Kajian ini menumpukan kepada cabaran pengajaran matematik dalam kalangan pelajar di Asia Tenggara, khususnya Malaysia, Indonesia dan Thailand di mana ramai pelajar menghadapi kesukaran dalam memahami konsep abstrak dan merasakan subjek tersebut tidak relevan dengan kehidupan seharian. Objektif kajian adalah untuk mengenal pasti cabaran khusus dalam pembelajaran matematik, membangunkan modul pembelajaran berasaskan permainan yang mengintegrasikan konsep asas matematik seperti algebra, statistik, kebarangkalian dan persamaan linear serta menilai keberkesanan modul tersebut dalam meningkatkan minat dan prestasi pelajar terhadap subjek matematik. Metodologi kuantitatif digunakan dengan melibatkan ujian pra dan pasca untuk mengukur peningkatan pencapaian pelajar serta tinjauan persepsi untuk menilai penglibatan, kepraktisan dan kepuasan pelajar terhadap modul pembelajaran yang dilaksanakan. Hasil kajian menunjukkan peningkatan signifikan dalam prestasi matematik pelajar selepas intervensi, dengan majoriti pelajar menunjukkan peralihan daripada tahap pencapaian rendah kepada pencapaian yang lebih tinggi. Impak kajian ini menunjukkan potensi pembelajaran berasaskan permainan sebagai inovasi pendidikan yang efektif, mampu meningkatkan motivasi, pemahaman konsep serta mengatasi cabaran utama dalam pengajaran matematik. Penemuan ini menyokong integrasi pendekatan pembelajaran inovatif berasaskan teknologi dalam sistem pendidikan secara lebih meluas.

Kata Kunci: Pembelajaran berasaskan permainan, Pendidikan matematik, Penglibatan pelajar, Inovasi pendidikan, Asia Tenggara

INTRODUCTION

Fostering student enthusiasm and competency in Science, Technology, Engineering and Mathematics (STEM), particularly in mathematics, remains a challenge for Southeast Asian nations such as Malaysia, Thailand, and Indonesia. According to the results of the Programme for International Student Assessment (PISA) 2022, Indonesia ranked 70th, Thailand 55th, and Malaysia 48th out of 79 participating countries (OECD, 2022). Approximately 70% of Indonesian students, 60% of Thai students, and nearly 50% of Malaysian students performed below basic proficiency levels in mathematics. These figures underscore a significant disparity in mathematical proficiency and interest among students within these Southeast Asian countries.

According to Denham (2017) and Adams et al. (2017), students frequently view mathematics as a challenging and abstract topic that is disconnected from real-world applications, which lowers their motivation and engagement levels. Their academic performance suffers as a result and they become less interested in going back to school or pursuing STEM-related employment. Addressing these educational issues is essential because mathematics plays a significant role in the development of critical thinking, problem-solving abilities and the fundamental knowledge required for scientific and technological advancement (Papadakis et al., 2021). In his well-known statement, "Mathematics is the queen of sciences," Carl FriedrichGauss emphasized the fundamental significance of mathematics in all scientific fields and the need for high-quality mathematics instruction (Gauss, cited in Bell & Pearson, 1991).

Considering these concerns, there is an urgent need for innovative teaching methodologies to enhance student engagement and performance in mathematics. Game-based learning has emerged as a promising educational approach, proven to significantly increase student motivation, enjoyment and conceptual understanding compared to conventional teaching methods (Pareto, 2014; Sarifah et al., 2022). The integration of interactive and engaging educational games can potentially overcome the negative perceptions and inherent challenges associated with mathematics learning.

OBJECTIVES OF THE STUDY

This study seeks to create, execute and assess a game-based learning module tailored to improve mathematics instruction in designated schools in Indonesia and Thailand. The research encompasses three explicit objectives:

i. Identifying Student Challenges in Mathematics

The initial goal is to determine the main challenges that pupils face when learning mathematics. According to existing research, students usually have difficulty understanding the abstract ideas, formulas, and intricate procedures that are part of mathematics curricula (Adams et al., 2017; Denham, 2017). Direct student input gathered through structured questionnaires will be used in this study to further investigate these issues.

ii. Implementing a Game-Based Module Incorporating Basic Mathematics

The second goal is to solve the highlighted obstacles by developing and implementing a tailored game-based module that incorporates basic mathematics concepts. According to research, educational games improve student interest and comprehension by offering a more engaging, accessible, and interactive learning environment. This leads to a considerable improvement in learning outcomes (Pareto, 2014; Sarifah et al., 2022).

iii. Evaluating the Effectiveness of the Module in Attracting Student Interest in Mathematics

The last goal assesses how the game-based learning module has affected students' interest in and attitudes toward mathematics. Questionnaires will be used in this quantitative assessment to gauge changes in students' interest and views after the intervention. Incorporating educational games into the mathematics curriculum has been shown to considerably increase student attitudes and achievement in previous meta-analyses and systematic reviews (Tokac et al., 2019; Vankúš, 2021; Liu et al., 2021).

METHODOLOGY

This study was conducted involving a total of 120 students: 70 Malaysian students and 50 students from three Southeast Asian schools, which are Madrasah Mualimin Muhammadiyah Yogyakarta, Madrasah Mualimat Muhammadiyah Yogyakarta (Indonesia), and Saiburi Wittaya School (Thailand). Students were randomly selected to ensure representativeness and reliability of findings (Cohen, Manion, & Morrison, 2017).

To understand the challenges students face in mathematics, a survey with 10 carefully designed

statements was distributed. Students responded using a five-point Likert scale ranging from "Strongly Agree" to "Strongly Disagree." Collected data were analyzed using Microsoft Excel. Two sets of Chi-Square tests were conducted. The first was an overall Chi-Square test, which was performed on the full dataset to determine if there were significant differences in how students responded across all statements collectively.

H0 (Null Hypothesis**):** There is no significant difference in student responses across all statements.

H1 (Alternative Hypothesis)**:** There is a significant difference in student responses across all statements.

Formula used:

$$\chi^2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \quad (1)$$

Where O_{ij} = observed frequency for row i, column j, and E_{ij}= expected frequency for row i, column j, which calculated as formula (2)

$$E_{ij} = \frac{Row\ Total_i \times Column\ Total_j}{Grand\ Total} \quad (2)$$

The second is individual Chi-Square Goodness-of-Fit tests, which were conducted for each statement individually to identify specific areas of difficulty.

H0 (Null Hypothesis): Student responses to each individual statement follow a uniform distribution.

H1 (Alternative Hypothesis):Student responses to each individual statement do not follow a uniform distribution.

Formula used to calculate χ^2 for each statement is shown as (3).

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i} \quad (3)$$

Where O_i = observed frequency for category i, and E_i= expected frequency for category i. E_i by using the formula (4).

$$E_i = \frac{Total\ responses}{Number\ of\ categories} \quad (4)$$

Based on the challenges identified from the initial survey, we developed a game-based educational module focused on fundamental mathematical concepts, specifically algebra, statistics, and linear equations. Educational games have been shown to improve engagement and understanding by providing interactive and practical learning experiences (Tokac, Novak, & Thompson, 2019). To measure the impact of this educational innovation, pre- and post-tests covering these topics were administered to students before and after using the module. The results from these tests were analyzed descriptively, using averages and percentage improvements calculated via Microsoft Excel, providing a clear overview of any changes in student performance.

To gauge students' perceptions of the developed module's effectiveness, an evaluation form comprising five questions was provided after module completion. Students rated their agreement on a scale from 1 to 5 regarding various aspects of the module, such as engagement, content relevance, ease of understanding, and practicality. Likert-scale evaluations effectively measure subjective experiences and satisfaction (Joshi, Kale, Chandel, & Pal, 2015). Responses were visually summarized using bar charts in Microsoft Excel, clearly presenting student evaluations and feedback on the module.

RESULT & DISCUSSION

To establish whether students' answers, taken as a whole, followed a uniform distribution, an overall Chi-Square test was applied to the response matrix (Table 1). The test produced a statistic of χ 2 = 189.32 with df = (10 − 1)(5 − 1) = 36. Using $\alpha = 0.05$, the critical value from the Chi-Square distribution is 50.99. Because 189.32 > 50.99, the null hypothesis, H0 is decisively rejected. In other words, the students did not answer the items at random; clear response trends exist.

To pinpoint where those differences lay, a separate goodness-of-fit test (df = 4) was run for each statement (Table 2). With $\alpha = 0.05$, the critical value is 9.49; equivalently, any p-value below 0.05 signals a meaningful departure from the uniform model.

TABLE 1. Chi-Square Statistic Table

Statements	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	0.007	1.896	4.691	0.045	0.670
2	0.827	5.772	1.798	0.850	0.298
3	3.161	3.300	0.521	4.425	8.600
4	3.015	12.986	19.670	2.079	3.391
5	4.802	0.145	0.011	3.487	0.019
6	0.289	5.089	0.521	5.474	2.460
7	0.494	0.055	0.011	0.001	3.391
8	1.340	4.450	1.798	4.425	2.460
9	4.622	14.064	4.691	35.196	0.019
10	0.007	3.969	0.011	4.626	3.391
		Total of Chi-Square (X^2)		189.319	
		Degree of Freedom		36	

TABLE 2. p-value for each statement with df=4

Statement	χ^2	*p-value*
Mathematics is difficult.	56.83	1.34×10^{-11}
Difficult to understand mathematical concepts.	82.68	4.74×10^{-17}
Mathematics contains too many facts, concepts, conditions, formulas, and procedures.	87.75	3.96×10^{-18}
Mathematics cannot be applied in the real world.	26.08	3.04×10^{-5}
There is no practical learning in mathematics.	38.42	9.19×10^{-8}
Mathematical logic is hard to visualize.	88.33	2.97×10^{-18}
Ineffective teaching by the teacher.	24.75	5.65×10^{-5}
There is no enjoyment in learning mathematics.	86.17	8.58×10^{-18}
Mathematics will not be implemented in our work.	34.00	7.45×10^{-7}
Mathematics should be an elective subject	8.00	9.16×10^{-2}

Eight of the ten statements produced p-values far below the threshold (e.g.,"Mathematics contains too many facts, conditions, formulas, and procedures," $\chi 2 = 87.75$, $p \approx 4 \times 10{-}18$). Students thus strongly converge on those items, revealing genuine pain-points: information overload, abstractness, lack of practice, and perceived irrelevance. The statement "Mathematics should be an elective subject" above 0.05 ($\chi 2 = 8.00$, $p \approx 0.091$). It fails to reach significance, suggesting opinions are mixed on whether mathematics should remain compulsory. These findings guided the instructional design: the module was built to trim cognitive overload, supply concrete applications, and strengthen conceptual bridges.

Figure 1 shows score distributions before and after the intervention. Prior to the module, marks clustered below 60 %, with only 4 % of students reaching 70 % or higher. Post-test results invert that picture: 69 % now score 70 % or above, while the lower bands (0– 49 %) shrink from 56 % to 11 %. Mean achievement rises from 47.3 % to 72.6 %, a gain of 25.3 percentage points. Although the present study reports descriptive statistics, the pronounced right-shift corroborates a substantial improvement attributable to the game-based approach.

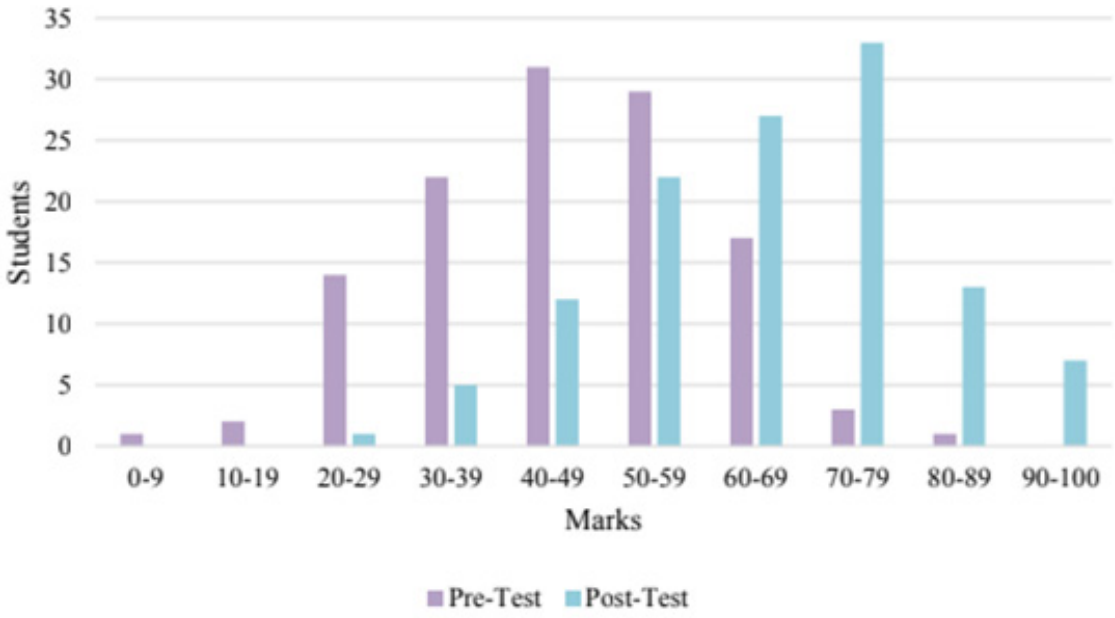

FIGURE 1. Student Performance Improvement (Pre-Test vs Post-Test)

Figure 2 depicts a distinctly right-skewed distribution of ratings across the five evaluation items, signaling a strong positive reception. Well over three-quarters of participants marked 4 or 5 for each statement, with the highest endorsement (92 %) recorded for the claim that the activities improved their understanding of mathematics. Roughly four in five students felt the module met their expectations for fun, interactive learning, while a similar proportion agreed that the tasks helped them transfer mathematics to real-world situations. Even organizational aspects were praised: two-thirds of learners rated the module easy to follow, and virtually none expressed outright disagreement on any item. Taken together, these results indicate that the game-based approach not only boosted achievement but also resonated with learners on engagement, relevance, and clarity.

FIGURE 2. Learner Perceptions of the Game-Based Mathematics Module (N=120)

The two-layered Chi-Square strategy paints a coherent picture. Broadly, students' attitudes toward mathematics are uneven, dominated by concerns over cognitive load and practical relevance. When the module targeted those precise issues through interactive tasks, real-life contexts and reduced procedural clutter, both performance and sentiment shifted in the desired direction. The sharp uptick in post-test scores implies that even short, game-based interventions can close fundamental skill gaps, echoing the meta-analytic conclusions of Tokac et al. (2019). Likewise, the high satisfaction scores align with prior work showing that well-designed educational games boost motivation (Denham, 2017).

Limitations include the descriptive nature of the learning-gain analysis and the reliance on self-report in the perception survey. Future work could integrate a controlled design and longitudinal follow-up to test the durability of gains.

CONCLUSION

In conclusion, this study successfully illustrates how incorporating game-based learning modules into Southeast Asian educational contexts, specifically Indonesia and Thailand, can greatly improve student performance, motivation and engagement in mathematics. The significant increase in students' mathematical proficiency and the overwhelmingly favorable opinions support the effectiveness of contextualized and interactive learning approaches. The focused game-based educational intervention successfully alleviated the conventional pain points that the students had clearly highlighted, including perceived irrelevance, abstract concepts and cognitive overload.

This approach not only tackles important issues in mathematics education, but also closely resembles previous research, highlighting the benefits of game-based learning environments. The results are encouraging enough to warrant more research despite certain drawbacks, such as the use of descriptive statistics and self-reported perceptual data. To confirm and bolster these findings, future research should think about using controlled experimental designs, growing participant groups and carrying out longitudinal studies. Overall, by highlighting creative approaches that can revolutionize mathematical learning experiences, this study makes a significant contribution to educational practice.

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