Effectiveness of Learning PEMDAS through Game-Based Learning for Primary Students

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Mathematics plays a vital role in our daily lives, not only in academic settings but also in solving real-world problems. Despite its significance, many individuals, particularly students in primary and secondary schools, struggle to grasp mathematical concepts. The challenges stem from difficulties in mastering various formulas and solving equations, which often lead to a lack of interest and motivation in learning mathematics. This issue calls for innovative teaching methods that are engaging and student-friendly. One promising solution is the implementation of game-based learning to enhance students' understanding and interest in mathematics. This project aims to improve mathematical engagement by achieving three main objectives: (1) to design a 2D game-based learning model for teaching mathematical methods, (2) to develop a 2D game-based learning application, and (3) to evaluate its effectiveness in enhancing students' learning. The Agile methodology was adopted for its flexibility and clarity in managing iterative development processes. In designing the game, the Mechanics-Dynamics-Aesthetics (MDA) Framework was applied, focusing on game mechanics, user interaction (dynamics), and overall experience (aesthetics). The effectiveness of the project was assessed using pre- and post-questionnaires. The results demonstrated a 54.07% improvement in students' understanding and interest in mathematics, indicating that game-based learning is a promising tool for enhancing educational outcomes. Thus, the project's objectives were successfully met. However, several limitations were identified. The current version of the game is limited to practising the order of operations, can only be accessed on desktop computers, supports only the English language, and does not allow players to choose or customise their characters. Future enhancements may include expanding the mathematical concepts covered, developing mobile-friendly versions for smartphones and tablets, incorporating multiple language options such as *Bahasa Melayu*, and enabling character customisation to improve user engagement. Overall, this project highlights the potential of game-based learning in making mathematics more accessible and enjoyable for young learners, laying the groundwork for future educational innovation.

Keywords: Game Based Learning (GBL), Mathematics, MDA, PEMDAS

INTRODUCTION

Mathematics is a tool for problem-solving and communication through mathematical computations [1]. Mathematical expressions are formed by mixing numbers and variables and applying operations like addition, subtraction, multiplication, division, exponents, and others. Learning mathematics has numerous advantages, including enhanced problem-solving abilities, mathematical skills, brain efficiency, and critical thinking. Mathematics has various applications in daily life, including banking and financial services, architecture, interior design, computer science, and many more [2].

Learning mathematics and teaching methods must be improved to have a positive impact on students' mathematical abilities and performance in the subject. Teachers have a crucial role in finding effective strategies for conveying mathematical concepts. Teachers should leverage technology to enhance learning and teaching experiences [3]. Mathematical topics such as algebra, calculus, and arithmetic should be taught in appropriate and efficient ways to encourage student absorption and enable them to take in and remember the content successfully.

Primary school students must develop a knowledge and comprehension of mathematics [4]. This is proven by the 2016 Ujian Pencapaian Sekolah Rendah (UPSR) results, which showed that around 95,147 students failed

the subject, accounting for 21.6% of the 440,496 candidates who took the test. Students continue to struggle to properly learn mathematics due to teachers' ineffective teaching methods, which has a detrimental impact on their enthusiasm for the subject [5]. The present teaching approaches today do not promote students' complete understanding of what is being taught.

Game-based learning (GBL) combines the learning process with the advantages of video games and related gaming elements such as information and images [7]. Implementing GBL into their learning environment can improve students' communication, creativity, and problem-solving skills. Furthermore, this strategy will assist students' study and increase their eagerness to learn [8].

Problem Statement

Mathematics knowledge is extremely important for students seeking optimum success in their daily lives. As a result, a strong interest in mathematics must be developed and instilled in them to use the concepts they are taught and have gained when needed. Some kids are intensely interested in mathematics but may hesitate due to their low mathematical performance and abilities. This is supported by Pranshi Sharma, in 2021, discussing the importance of mathematical applications in daily life, which shows that most kids like mathematics; however, due to some lack of mathematical skills, more than half of the survey cannot excel in mathematics.

For students who have the potential to excel, a lack of conceptual understanding of mathematics may result in a decline in performance [6]. A solid understanding is required to ensure that their learning outcomes are strong and indirectly, a firm grasp is essential to succeed. Students may lose interest in the subject matter if they cannot grasp the concepts.

Objectives

Therefore, this project will use technology through GBL to increase interest in mathematics. The effectiveness of using GBL was measured to evaluate their performance in PEMDAS mathematical skills for children aged 10 to 12 years old. This paper will cover literature review, methodology, results and discussion, and conclusion of the project.

Product Description & Methodology

The study employs a quasi-experimental design with two groups: an experimental group using game-based learning tools and a control group following traditional instruction. Pre-tests and post-tests are conducted to assess their understanding of PEMDAS.

The test phase is the final stage of Agile methodology, in which the final product is completed and ready for testing and evaluation. The target audience for this project is chosen, and the project is tested to ensure that it functions properly and without errors. Any flaws and issues discovered during the testing period are resolved and improved.

The platform used to collect information on evaluating the effectiveness of the PEMDAS: Order of Heroes game is Google Forms. The game is provided to participants so that they can download and play it. The target audience for this project is school students aged 10 to 12 years old, who are given a questionnaire to evaluate their PEMDAS skills before and after the game is played. The procedure for the evaluation that is performed is as in Fig 1.
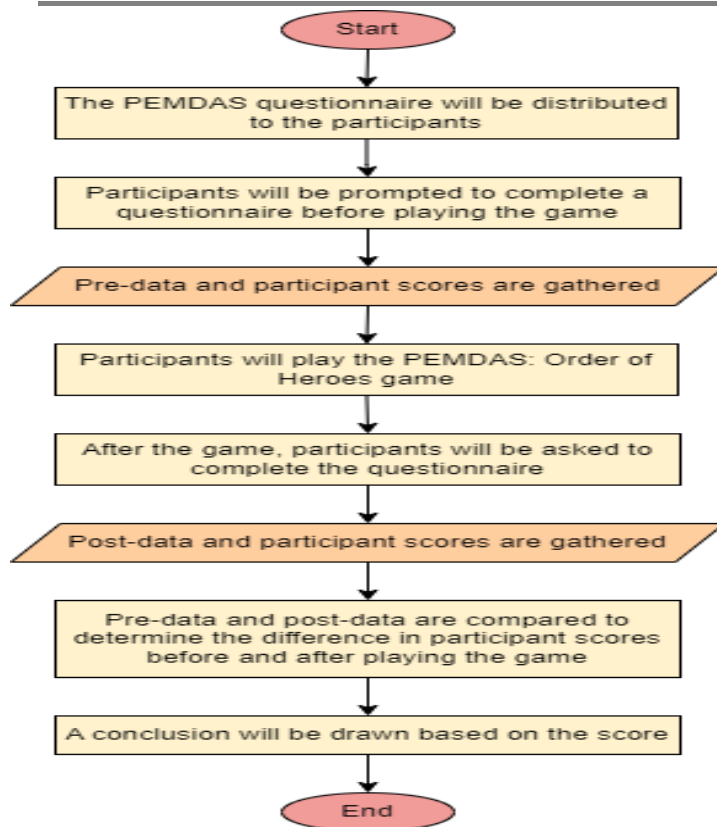
Fig 1. Experiment procedure

Scores are assigned for each question answered by the participant. To evaluate the test's effectiveness, scores are compared before and after playing the game. Participants are given time to complete the questionnaire before playing the game, to assess their knowledge of PEMDAS. The participants' PEMDAS questionnaire scores after playing the game are expected to be higher than before. If the prediction is true, the game is expected to be effective in teaching participants how to answer mathematical equations using PEMDAS.

The user's score plays a crucial role in determining the effectiveness of the PEMDAS: Order of Heroes game in achieving the objectives of this project. In this case, effectiveness is the aspect that needs to be assessed for the game. The PEMDAS questionnaire was used to evaluate the game's effectiveness based on users' scores before and after playing the game. This questionnaire presents users with several math questions in three difficulty levels: Basic, Moderate, and Difficult.

The testing was conducted at Sekolah Kebangsaan Seri Mendapat, involving 16 students from fifth grade as participants to evaluate the effectiveness of the game PEMDAS: Order of Heroes. The number of participants was small because the school has a low student population due to its location in a rural area. The same questionnaire was given to the students before and after they played the game.

The questionnaire consists of 14 math questions. These questions, which were included in an online survey using Google Forms, involve mathematical operations and word problems that require users' problem-solving and critical thinking skills.

Table 2 The PEMDAS Question

PEMDAS Question		Source
Basic		
1.	$53 + 53 + 53 + 53 + 53 + 53 + 27$	

2.	$34 + 102 + 102 + 102$	(Anupama S.M. B, 2020)
3.	$17 - 25 - 25 + 17 + 17 + 17 + 17 - 25 + 17$	
4.	$12 - 3 - 3 + 2 - 3$	
5.	5×3	(Sümen, 2022)
Moderate		
6.	$5 \times 2 + 4$	(Anupama S.M. B, 2020)
7.	$3 + 4 \times 5$	
8.	$5 \times (7 - 2)$	(Sümen, 2022)
9.	$(3 + 2) \times 4$	
Difficult		
10.	$(6 / 2) \times (3 + 4)$	(Sümen, 2022)
11.	$4 + (8 / (4 \times 2))$	
12.	$6 \times 5 - 8 \div 2$	(Anupama S.M. B, 2020)
13.	Sanu packs 12 apples in a box. She was able to fill 3 boxes, but 2 apples were left out. How many apples did she have?	
14.	3 out of 24 mangoes in the basket were rotten. Chandar and his two friends share the remaining mangoes. How many good mangoes does each of them get?	

Potential Findings and Commercialisation

Effectiveness Evaluation

The questionnaire consists of three levels of difficulty: basic, moderate, and difficult.

Table II above shows the stacked graph of Percentage of Correctness by Questionnaire Levels, comparing pre-test and post-test. Based on the data, there was a clear improvement after the intervention. For basic-level questions, the correctness increased from 60% to 80% of respondents, while moderate-level questions improved from 61% to 81%, showing a 20% increase in the correctness of answering questions. The most significant improvement was seen in difficult-level questions, where the correctness jumped from 30% to 69%, resulting in a 39% increase. This shows that participants initially struggled with more challenging questions but made significant progress after the intervention. The consistent 20% increase in basic and moderate questions indicates a better understanding of foundational concepts, while the higher improvement under challenging questions shows stronger problem-solving skills. Overall, the results prove that the game effectively enhanced learning outcomes across different difficulty levels.

Overall Findings

Based on Table 2 below, there is a down percentage of the participant's score for the pre-test and post-test, N6. The total score in the questionnaire is 14. The score obtained on the pretest is 10, and the post-test is 5, which leads to a reduction of -35.72%. For example, in the first moderate question in the pretest, the participant answered correctly with 14, but in the post-test, the participant answered with 30. This could be because the

participant miscalculated multiplication before addition. The score reduction is likely because there is a misunderstanding of PEMDAS rules after playing the game and overconfidence that leads to careless mistakes.

The participant with the highest percentage of the participant's score improvement is N12, with 57.15%. The score for the pre-test is 5, while the post-test is 13. For example, in the third basic question in the pretest, the participant answered with 0, indicating the struggle with multiple operations, but in the post-test, the answer was 27, which is correct. In the fourth difficult question, the participant miscalculated the answer with 36 in the pre-test, but in the post-test, the participant answered it correctly with 38. The possible reason for the improvement is probably because the participant made careless mistakes in the pretest and did not understand the questions.

Table 2 Score Analysis

Participant (N)	Pre-test	Post-test
N1	9	12
N2	7	12
N3	9	12
N4	6	10
N5	5	10
N6	10	5
N7	2	8
N8	5	10
N9	6	13
N10	7	10
N11	7	11
N12	5	13
N13	7	11
N14	8	10
N15	9	14
N16	9	10

A paired samples t-test was conducted to evaluate the effect of the intervention on participants' test performance. The results indicated a statistically significant difference between the pre-test (M = 6.94, SD = 2.08) and post-test scores (M = 10.69, SD = 2.15), $t(15) = -5.11$, $p < .001$ (two-tailed). This suggests that the intervention had a significant positive impact on participants' performance. The mean increase in scores implies that participants demonstrated improved understanding or skill acquisition following the intervention. Given the large t-value and extremely low p-value, we reject the null hypothesis and conclude that the difference is not due to chance.

Novelty and Recommendations

Game-based learning effectively teaches PEMDAS to primary students, as it enhances comprehension, engagement, and motivation. Future research should explore the long-term impact of GBL and its integration with other mathematical topics. Educators are encouraged to incorporate game-based strategies into their teaching methods to improve student outcomes.

Being good at mathematics is an important skill that can assist many people. However, most students, especially primary school students, cannot fully understand the basics of mathematics. They find it hard to grasp the concepts and lack interest in learning them since mathematics is a difficult subject for them. The reason this project was created is to solve these problems. This project can assist students in effective learning with engaging materials.

This project aims to provide effective and engaging mathematics game-based learning that can be played by all people, especially students. Game-based learning is a suitable tool for learning since it provides attractive elements that can attract students' attention and interest.

The feedback from the users who are primary school students is important to see if this project meets the objectives. To calculate the effectiveness of this game in providing mathematics lessons, a questionnaire was used to evaluate it. The questionnaire can help to see and conclude that this project managed to achieve all objectives. To make sustain the effectiveness testing, the number of participant can be gather up to 30 people, so that the results can be more

As a conclusion, mathematics learning can be interesting and engaging by using the PEMDAS: Order of Heroes game in the learning process. The evaluation of the user's feedback has proved that this game is effective in teaching primary school students using online questionnaires. By implementing a game-based learning method, problems like a lack of interest in the mathematics subject and difficulty in understanding the lesson can be solved. In a future, some improvements can be made in the future to enhance this project such as expanding mathematics concepts in the game to allow players to learn more than just the PEMDAS concept, developing a game that can be played on smartphones, tablets, and other mobile devices, adding multiple language options such as Bahasa Melayu for non-English speakers and allow player to choose and customize their character in the game.

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