

# Development and Usability of Games in Learning Mathematics

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**Abstract**—Game-based learning is important in helping teachers attract students' interest in learning. Therefore, this study developed and investigated the usability of a game, namely Pirates Mathsdom, which was used to strengthen the students' understanding of learning mathematics. The research design used is ADDIE model. A total of 30 pre-service mathematics teachers in Perak, Malaysia, were randomly selected. A questionnaire is developed to investigate the usability of Pirates Mathsdom and then analyzed using descriptive analysis and mean scores. Findings show that this game has a high validity and reliability value, with a Content Validity Index value of 1.00. Meanwhile, the level of usability is high, with the mean score values for each construct being 3.77 (design), 3.79 (ease of use), and 3.75 (satisfaction), respectively. The implication of the study is to promote games as one of the learning tools to attract students' interest in mathematics.

**Keywords**—ADDIE model, development, game-based learning, games, usability

## I. INTRODUCTION

A teaching method is important for a teaching and learning process where this method is used to improve students' participation and achieve the learning outcomes. The traditional teaching method is frequently used in teaching and learning, especially in mathematics. The main reason that the teachers are unwilling to change their teaching method is because they are already at ease using the conventional teaching style. However, traditional teacher-centered learning reduces student enjoyment and causes boredom, today's students are not interested in such teaching strategies. According to Ref. [1], non-traditional methods are more suitable for teaching and learning mathematics. This is because active learning is required for the mathematics curriculum to increase students' motivation for learning.

Furthermore, Mahalingam and Khairul [2] stated that the level of thinking of students nowadays still requires teaching materials that are simple and easy to understand because there is no guidance from educators. According to the statement, today's students spend more time with technology than they do with humans. They would rather

play with electronic devices than talk with friends. As a result, chalk-and-talk learning is already less relevant to today's students' learning. They would rather use the internet to access the information than ask the teacher. This results that, game development is the best initiative for providing students with the opportunity to explore using the medium of their choice. The development of games will allow them to explore and build knowledge that is meaningful to them. Furthermore, digital games can provide fun in the subject of mathematics compared to traditional learning, which often fails to arouse students' interest in what they learn in class [3].

In line with current technological developments, the Ministry of Education (MoE) Malaysia is implementing the seventh transformation in the "Malaysian Education Development Plan (PPM) 2013–2025". The MoE stated in the PPM 2013–2025 that it intends to use Information and Communication Technology (ICT) to improve learning quality. As a result, teachers are advised to use technology-enhanced teaching aids to ensure that planned learning is effective with active student participation, as well as the ability to produce students who think creatively and critically. Thus, this study was conducted based on the needs of teachers to develop an initiative or approach in the form of technology in teaching to achieve the Ministry of Education and Culture's wishes. Furthermore, digital game-based learning methods in the mathematics teaching and learning process are in line with 21st-century learning, which is actively implemented in the educational system [4]. As a result, developing a digital game is an effective step toward increasing the use of technology and applying 21st-century learning.

Game-based learning is a learning activity that embeds the game's characteristics and principles. Game-based learning can encourage students to participate actively in the learning process. This is because this learning method is more focused on attracting students' interest and improving their enjoyment of the learning process. Students' interest in actively participating in learning can improve their skills and knowledge directly.

Moreover, game-based learning provides students with interesting learning characteristics through activities that increase extensive exploration in addition to being able to improve competitiveness in students. This learning method also encourages active learning through more

innovative methods, so that learning can occur naturally without any prompting or with minimal guidance.

In this study, a game, namely Pirates Mathsdom for the topic of straight-line gradient in Mathematics Form 2, is developed based on one of the mathematics topics in secondary school level. This game was developed to assist teachers in helping students understand the concept of a straight-line gradient. This game can also assist teachers in ensuring students are not bored during the teaching and learning session. This is because traditional teaching combined with technology can have a positive impact on mathematics learning [5]. According to Ref. [6], mathematics is considered one of the most difficult subjects because the teacher's teaching method in school focuses more on traditional teaching methods such as chalk and talk, so the teacher should diversify teaching methods so that teaching and learning sessions become more effective. As a result, game-based learning that incorporates the concept of learning while playing makes students more proactive during the learning process and facilitation session because they can explore and apply the concept on their own.

## II. METHODOLOGY

### A. Research Design

The research design of this paper is quantitative research and the model used in this study is ADDIE model. This model is used to develop and measure the usability of Pirates Mathsdom. The ADDIE model is a design model that can be used to create software or teaching and learning materials based on systematic needs. The production of

these teaching aids is divided into five phases: analysis, design, development, implementation, and evaluation. The development of Pirates Mathsdom must follow the ADDIE model's five phases to make the study planning clearer and more organized. This is because the output of one phase becomes the input for the next. Each phase is linked to the previous one, demonstrating that this model necessitates regular planning to produce high-quality materials.

Fig. 1 shows the flow chart of the ADDIE model for this study [7]. In the first phase, which is the analysis phase, a needs analysis was created to determine the problem statement, objectives, the study's needs, and the steps that must be taken to overcome the problem. During the design phase, a storyboard of the game is developed as a reference. Furthermore, research instruments were built to evaluate its validity. This game is then developed in the third phase, which is the development phase, using the storyboard created in the design phase. Experts are then evaluating the game's development using face and content validity questionnaires to ensure that the game can be used in the implementation and evaluation phases. Then, during the implementation phase, a pilot study was conducted to ensure that no errors or mistakes occurred when using instruments and games in the actual study. The evaluation phase is carried out to determine whether the game can meet the study's objectives or not.

Fig. 2 shows the interface of Pirates Mathsdom. In this game, a player must complete all the given questions from each of the four islands to win the game. The objective of this game is to increase students' enjoyment when learning mathematics.

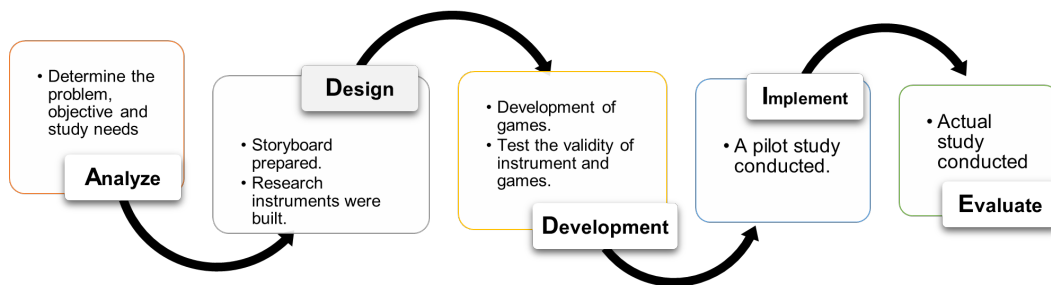


Fig. 1. ADDIE model.



Fig. 2. Interface of Pirates Mathsdom.

### B. Sample and Data

A total of 30 mathematics pre-service teachers from Perak, Malaysia, participated in this study. The sample size selected is sufficient for this study because the

minimum sample size selected for the study is 30 respondents [8]. The sample was selected using a simple random sampling technique. All responses can be fairly and impartially chosen using this method. Each respondent has a good likelihood of being chosen.

C. Research Instrument

A questionnaire was employed in this study. Two questionnaires have been developed to measure the validity and usability of the game. The questionnaires were developed and modified by [9–11]. A 4-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Agree, and 4 = Strongly Agree) is used in this questionnaire. The instruments have been validated by three experts to ensure the face and content of the instruments before being distributed to the respondents.

D. Pilot Study

A pilot study was carried out to evaluate the level of reliability of the questionnaire [12]. Therefore, before the actual study is conducted, a pilot study is important to determine the validity and reliability of the questionnaire. There are 15 respondents from the mathematics pre-service teachers who participated in the pilot study. This is because Isaac and Michael [13] and Hill [14] believed that the sample size for a pilot study should be between 10 and 30 people. The data from this pilot study was then analyzed using Cronbach’s alpha to determine the reliability of the instruments. Table I shows the value of Cronbach’s alpha and its interpretation.

TABLE I. INTERPRETATION OF CRONBACH’S ALPHA

Cronbach’s Alpha Value	Reliability Level
0.81–1.0	High
0.71–0.8	Good
0.61–0.7	Fair
< 0.6	Item needs to be improved
< 0.5	Item should be dropped

Findings show that Cronbach’s alpha obtained for this study is 0.828. This explains that the reliability of the instrument is high level. According to Ref. [15], a Cronbach’s alpha value of 0.8 to 1.0 indicates a very good and effective level of reliability with a high level of consistency. As a result, the instruments used have a high level of reliability and can be used in the studies.

E. Data Analysis

The data obtained from the experts’ validity questionnaire is analyzed using the Content Validity Index. The CVI value is calculated using Eqs. (1) and (2):

$$Item\ Content\ Validation\ Index\ (I - CVI) = \frac{Sum\ of\ experts'\ score}{Total\ of\ all\ score} \tag{1}$$

$$Content\ Validation\ Index = \frac{Sum\ of\ I - CVI}{Number\ of\ expert} \tag{2}$$

According to Ref. [16], an I-CVI value that exceeds 0.78 based on the evaluation of three or more experts is considered to have good validity. Then, the mean score for four-point Likert scale is used to measure the usability of the Pirates Mathsdom. Table II depicts the value of mean score with its interpretation.

TABLE II. INTERPRETATION OF MEAN SCORES

Mean Score	Interpretation
1.00–1.50	Not Relevant
1.51–2.50	Low
2.51–3.50	Medium
3.51–4.00	High

The mean score in the range of 1.00–1.50 in Table II indicates that the game that was developed is not relevant. The mean score value of 1.51–2.50 indicates that the game’s usability is low. Meanwhile, the mean score value indicating the game’s usability at a medium and high level is between 2.51–3.50 and 3.51–4.00, respectively.

III. RESULTS AND DISCUSSION

A. Validity of the Game

Table III shows the findings of the validity test for Pirates Mathsdom. The results show that Pirates Mathsdom has high validity, as the total CVI score for each expert on face and content validity is 1.00.

TABLE III. CONTENT VALIDATION INDEX (CVI)

Validation Construct	CVI Value			Total
	Expert 1	Expert 2	Expert 3	
Face	1.00	1.00	1.00	1.00
Content	1.00	1.00	1.00	1.00

B. Usability of the Game

The findings include the demographics of the respondents as well as the respondents’ evaluation of the game’s usability based on the three constructs provided, which are design, ease of use, and satisfaction.

1) Demographic respondents

The demographics of the respondents are summarized in Table IV. Table IV shows that 21 females (70.0%) participated in this study, compared to 9 males (30.0%). Meanwhile, the nation of the respondents included the Malay (76.7%), followed with the Chinese (13.3%), other races (6.7%), and Indians (3.3%).

TABLE IV. DEMOGRAPHIC RESPONDENTS

		Frequency	Percentage (%)
		Gender	Male
	Female	21	70.0
Nation	Malay	23	76.7
	Chinese	4	13.3
	Indian	1	3.3
	Other	2	6.7

2) Design of the game

The findings about the game design are shown in Table V. Table V shows the highest mean score for item 4 at 3.83. This explains that the use of colors, numbers, and animations in Pirates Mathsdom is appropriate. Meanwhile, the lowest mean score obtained was 3.70, which refers to the font size used (item 2), and the game is simple to use (item 7). Overall, the mean score value is high (3.77) for most pre-service teachers’ perceptions of the game design. This shows that items related to the

design of games are also accepted as appropriate and interesting (high).

TABLE V. DESIGN OF PIRATES MATHSDOM

No.	Item	Mean Score
1	The design of Pirates Mathdom is appealing.	3.80
2	The font size used in Pirates Mathdom is appropriate.	3.70
3	The font type used in Pirates Mathdom is appropriate.	3.80
4	Pirates Mathdom's use of colors, numbers, and animations is appropriate.	3.83
5	Pirates Mathdom works well.	3.73
6	The instructions in Pirates Mathdom are clear.	3.77
7	Pirates Mathdom is simple to use.	3.70
8	Overall, the design of Pirates Mathdom is adequate.	3.80
Total Mean Average		3.77

### 3) Ease of uses of game

The highest mean score for this construct is 3.83, which refers to items 1, 3, and 5 in Table VI. This shows that Pirates Mathsdom is easy to use, has clear instructions, and gives clear steps for completing the games. Meanwhile, the lowest mean score obtained is 3.67, which is item 2. This shows that the games should be more user-friendly, which will make it easier for users to access the games in the future. From the findings, the Pirates Mathsdom has a good or satisfactory ease of use, and the average overall mean score for this construct is 3.79, which is high.

TABLE VI. EASE OF USES OF PIRATES MATHSDOM

No.	Item	Mean Score
1	Pirates Mathdom is easy to use.	3.83
2	Pirates Mathdom is user friendly.	3.67
3	Pirates Mathdom has clear instructions.	3.83
4	The use of Pirates Mathdom simplifies both teaching and learning.	3.77
5	Pirates Mathdom has step-by-step instructions.	3.83
Total Mean Average		3.79

### 4) Game satisfaction

Table VII displays the satisfaction level of the users with the game. The highest mean score for the construct is 3.77, which gives positive feedback for the games. This explains that the games seem to give the teacher the opportunity to use them in the class and can attract students' interest in mathematics subject. Meanwhile, the mean score for another three items, including items 1, 3, and 5, is 3.73, which is at a high level. The overall mean score for this construct is 3.75, which is high. It can be concluded that the Pirates Mathsdom has a high level of satisfaction.

Game-based learning is regarded as a catalyst for accelerating learning through active student participation, which can then provide an injection of enthusiasm to excel in academic achievement [17]. If the game developed has a high level of usability, it can assist teachers in ensuring that students are able to engage actively, provide

understanding, and be interested in learning the topic. Moreover, teachers can use this game as an assessment tool. Therefore, Pirates Mathsdom can be built and used as a teaching aid since it has high validity and usability.

TABLE VII. GAME SATISFACTION

No.	Item	Mean Score
1	I enjoy using Pirates Mathdom in my classroom.	3.73
2	I am pleased to be able to use Pirates Mathdom in both teaching and learning.	3.77
3	Pirates Mathdom can assist me in teaching more effectively.	3.73
4	Pirates Mathdom can help students become more interested in this subject.	3.77
5	Pirates Mathdom can assist students in coming up with ideas when studying this topic.	3.73
Total Mean Average		3.75

## IV. CONCLUSION

The development of Pirates Mathsdom has had a positive impact on pre-service teachers since Pirates Mathsdom has a high level of usability. This shows that all three constructs of game usability evaluation received a high average mean score, which are 3.77 (design), 3.75 (ease of use), and 3.79 (satisfaction). Furthermore, the pre-service teachers also agreed that Pirates Mathsdom is simple to use and meets the needs of its users. Therefore, the Pirates Mathsdom game can be used as a learning tool for teaching and learning processes, in addition to improving the quality of learning among students.

The use of games can help students improve their academic achievement and further cultivate a positive attitude towards learning the subject. A game is also important to save teaching time because there is no need to waste time making further explanations; instead, by using an appropriate game, students will be able to understand the content presented more easily. Thus, games are very useful for teachers to get the full attention of students and create a great environment in teaching and learning sessions.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## AUTHOR CONTRIBUTIONS

S. Y. Phoong and Nurul Fashihah Yaakub conceived of the presented idea; Nurul Fashihah Yaakub conducted the research and analyzed the data; S. Y. Phoong was in charge of overall direction and planning. S. Y. Phoong and Nurul Fashihah Yaakub wrote the paper; all authors had approved the final version.

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