When Games get in the way: Gamification Approach for Teaching Maths – A Case Study With Undergraduate Tourism Students

Sónia Pais[1,2] and Andreia Hall[1]
[1]CIDMA, Center for Research and Development in Mathematics and Applications, University of Aveiro, Aveiro, Portugal
[2]CITUR – Centre for Tourism Research, Development and Innovation, Polytechnic Institute of Leiria, Leiria, Portugal

sonia.i.pais@ipleiria.pt
andreia.hall@ua.pt

Abstract: Planning more dynamic and motivating lessons for students is the goal of any teacher, especially maths teachers, a subject where the lack of interest and motivation to learn is so evident and a major concern. Several studies highlight the positive impact of the adoption of gamification strategies in teaching/learning, both in student motivation and in the development of soft skills (teamwork, creativity, decision-making, leadership, communication, and critical thinking). Game-based learning thus promotes students' interest and involves them in this process. In this sense, one of the authors of this study chose to use several (non-digital) games to support the teaching-learning process in her classes. The games used were developed by the authors and have been thoroughly designed to address specific maths topics. The games took various forms, including card games, board games and other hands-on activities. The participants in the study are first-year undergraduate students from a Portuguese higher education institution and encompassed the course of "Quantitative Methods". The aim of the study is to investigate students' perceptions of the use of gamification in the maths teaching-learning process. To gather information about students' insights on the use of games in math classes a quantitative survey was conducted. Similar studies have shown that higher education students are usually receptive to the use of games, finding it useful to increase their motivation and consider game-based learning can positively impact learning. Our findings are in line with those studies.

Keywords: Educational Games, Gamification, Non-digital Games, Mathematics Education, Pre-service Teachers.

1. Introduction

Maths education is crucial in today's educational landscape. However, it has raised concerns due to persistent academic and educational failures, as documented by various researchers (e.g., Pais, Cabrita and Anjo, 2011; Faulkne, Hannigan and Fitzmaurice, 2014; Pais and Hall, 2021; Santos et al., 2021; Maharjan et al., 2022; Morando and Turconi, 2022; Morando and Spreafico, 2023). Studies highlight a lack of student interest and motivation in mathematics as a key factor contributing to this failure (JMCUK, 2011). This is particularly evident for students in non-maths-focused programs, such as tourism degrees (Pais and Hall, 2021; Santos et al., 2021).

Game-based learning (GBL) can be a pedagogical resource and a good strategy in the classroom to support mathematical learning and, at the same time, reveal the pleasant and stimulating perspective of learning thus motivating students to learn maths (Pais and Hall, 2021; Morando and Turconi, 2022; Morando and Spreafico, 2023). A systematic review carried out by Erşen and Ergül (2022) highlights that teaching with games increases academic performance, has a positive impact on attitudes toward mathematics, and that students positively evaluate the use of games in the mathematics teaching-learning process.

With the aim of seeking strategies to foster interest in mathematics, motive student enthusiasm and make the learning process itself more engaging, the first author of this work decided to use several (non-digital) games to support the teaching-learning process in her classes. The games used either pre-existing educational games or adaptations of original games by mathematicians Maria Luisa Spreafico and Paola Morando, known for their expertise in designing maths games (La Fortuna et al., 2022; Morando & Turconi, 2022; Morando & Spreafico, 2023). All the games were meticulously planned to address specific mathematical topics. The games took various forms, including card games, board games and other hands-on activities.

The study here presented involved the students of "Quantitative Methods" (1st semester of 2023/2024), a first-year course in the "Restaurant and Catering Management" bachelor's degree, offered by a higher education institution specializing in undergraduate degrees in Tourism.

1.1 Non-Digital Game Based Learning

Oldfield (1991) defines a mathematical game as a social activity with rules, structure, goals and specific mathematical cognitive objectives.

Non-digital games are those that don't depend on any electronic device to be played. They can range from puzzles, card games, board games to hands-on activities (Connoly, Stansfield and Hainey 2007).

Despite the numerous advantages of technology, inclusively when used in gamification activities, the authors opted to use non-digital games instead of digital games. In today's digital/technological world, young people are surrounded by screens and spend countless hours “looking” at them. The excessive use of technology is compromising the quality of social interactions, leading many of our young people to social isolation and difficulties in communicating and establishing relationships (Paiva and Costa, 2015). Thus, the authors deliberately wanted to provide their students with a break from the digital world and screens. In addition, non-digital games have other benefits (Ramos, Knaul and Rocha 2020), such as: (i) improving social relationships; (ii) promoting teamwork and cooperation; and (iii) face-to-face interaction and communication with others.

2. Methodology

2.1 Research Aim, Procedure, and Instruments

This study investigated whether integrating game-based learning strategies throughout the "Quantitative Methods" course could increase student motivation and engagement, particularly for students in the Tourism program, when learning mathematics. To achieve this, the authors employed a case study with primarily exploratory objectives.

Bearing in mind the aim of the study, the authors developed a questionnaire for the students who attended the course under evaluation, described and analysed in Section 4.2. A preliminary version of this instrument was analysed by two higher education teachers, tested with three individuals from the same group, and modified based on the suggestions collected and difficulties detected during its completion. Since one of the authors of this article was the teacher responsible for the course in question, the technique of direct observation was also applied, using field notes.

At the end of the semester, students were asked to fill in the questionnaire. The questionnaire was distributed online to the students who attended the classes and aimed to assess the students’ opinion on the changes made to the way the course was taught. After data collection, qualitative analyses were carried out, quantified whenever necessary and possible. A descriptive analysis was performed, using heatmaps and graphical representations of responses as well as the calculation of the mean and standard deviation of quantitative responses. The analyses were performed with Excel.

2.2 Participants

The case study was conducted at a higher education institution in the central region of Portugal. The participants were undergraduate students majoring in “Restaurant and Catering Management”, specifically enrolled in the “Quantitative Methods” course during the first semester of the academic year 2023-2024. The case study included a total of 12 students, with 9 of them completing the questionnaire. Among the respondents, 6 (66.6%) were female, and 3 (33.3%) were male. The age of the participants ranged from 18 to 21 years. It is important to note that this was a convenience sample, meaning that the participants were easily accessible to the researchers.

2.3 Study Description

The course content was divided into three main topics: elementary mathematics applied to restaurant and catering management, applied mathematics for management, and statistics. The course consisted of 22 two-hour classes, and games were incorporated into 9 of these classes.

The first topic primarily involved reviewing basic mathematics concepts from elementary school. It was divided into four subtopics: arithmetic operations, decimals and fractions, ratios, proportions, percentages, and units of measurement. Due to students' lack of prior knowledge, eight classes were dedicated to this topic (two classes for each subtopic). Games were used in four of these eight classes, in the second half of the last class for each subtopic.

The second topic covered polynomial functions, exponential functions, and logarithmic functions, as well as their applications in financial modelling. Eight classes were required to cover this topic, two per subtopic. Game-based learning was used to practice problem-solving in two of these classes.

The last six classes were dedicated to the third topic: descriptive statistics and linear regression. Games were used in two of these six classes – one after completing the classes on frequency tables, graphical representations, and sample statistics (central tendency and dispersion), and another in the last class for practicing problem-solving.

A total of five different games were used: "SuperTmatik"; "Fractions Dominoes"; "Math Twins" (in two different setups); "Problem Basket" (in three different setups); and "StatPictionary". Table 1 specifies which games were used to address each of the program topics.

The purpose of using the games was to provide students with a better learning experience, engaging them in the learning process and promoting their interest.

Table 1: Games played

Topics	Game	Contents	Class number and game version
Elementary mathematics applied to catering and restaurant management	SuperTmatik	Review of arithmetic operations	Class 2
	Fractions Dominoes	Review of decimal numbers and fractions	Class 4
	Math Twins	Review of decimal numbers and fractions	Class 4 Version 3
		Measurement units	Class 6 Versions 2 and 3
	Problem Basket	Review of ratios, proportions, and percentages	Class 8
Applied mathematics for management	Problem Basket	Polynomial functions	Class 11
		Exponential and logarithmic functions	Class 16
Statistics	StatPictionary	Frequency tables, graphs, statistical measures (central tendency and dispersion)	Class 20
	Problem Basket	Dispersion statistics, linear regression	Class 22

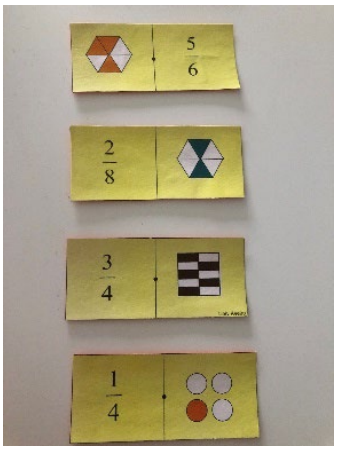
3. Presentation of the Games Played

Out of all the games played, only one was not developed by the authors of this paper – "SuperTmatik" – an educational game developed by Eudactica, widely used in school settings since 2005, with national school competitions held in various countries.

The games were developed considering the principles of educational game design and development described in the diverse existing bibliography (Whitten & Moseley, 2012; Kapp, 2012; Nicholson and Cable, 2020). Next, each of the four games adapted by the authors is described.

3.1 Fraction Dominoes

This game is a variation of the popular Dominoes. It features pieces with a number (fractional or decimal) on one side and a corresponding diagram on the other (see Figure 1). Players take turns matching either the number or the diagram with the pieces already played on the table. The first player to get rid of all their pieces wins.



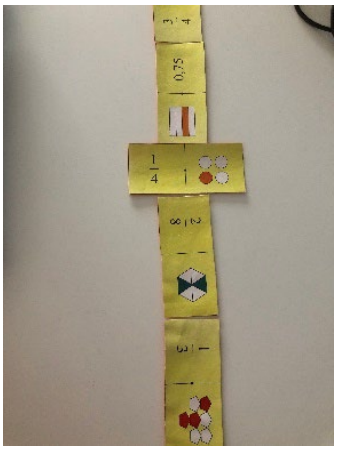


Figure 1: Examples of pieces and chain of "Fraction Dominoes"

Materials Needed:

- one set of dominoes for each group of 4 players;
- a die.

Game instructions:

- Four players form a group.
- The 28 pieces are shuffled, and each player draws seven.
- To determine the starting player, everyone rolls a die. The player with the highest roll begins.
- On their turn, players must attempt to place one of their pieces on either end of the existing domino chain. They can strategically choose which end to play based on their hand.
- If a player successfully places a piece, their turn ends, and play moves to the next player.
- If a player has no piece that fits either end, they must pass their turn without playing.
- The game ends when one player gets rid of all their pieces, or when the game becomes deadlocked (no player can play a piece). In a deadlock, the winner is the player with the fewest remaining pieces.

3.2 Mathtwins

"Mathtwins" is a variation of the popular memory game where you must find pairs of identical elements or elements that are matched in some way.

Materials Needed:

- a deck of cards paired in pairs.
- a timer.

Game instructions:

Version 1 (Game for a large group):

- Match the number of cards to the number of players (which must be even) by removing some pairs from the deck if necessary.
- Deal the cards, one to each player.
- Silently, each player must find his pair.
- The first successful pairs of players earn a reward.

Version 2 (Game for 4 teams of 1-2 players):

- The number of cards in the deck must be an even multiple of the number of teams.
- Deal the whole deck to the teams.
- Each team must check if they have any pairs in their hand and put them aside. They have one minute to do this.
- Then, simultaneously, each team draws a random card from the team next to them and checks again if they can form a pair. They have one minute to do this.
- Repeat this step until one team has no cards left. That team wins the game.

Version 3 (Game for a large group divided into teams):

- For this version you must have as many decks as teams.
- Each team receives a deck and displays the cards on a table.
- For 3 minutes (or another time stipulated by the teacher), the teams must look for pairs in the deck.
- The team that has found the most pairs at the end of the time wins.

"Mathtwins" was played in two different classes, exploring two distinct topics: measurement units and rational numbers. The first deck comprised pairs of corresponding measures expressed in different units, as illustrated in Figure 2 (left). The second deck involved pairs of rational numbers that add up to 1, with one number in fractional form and the other in decimal form (see Figure 2, right).

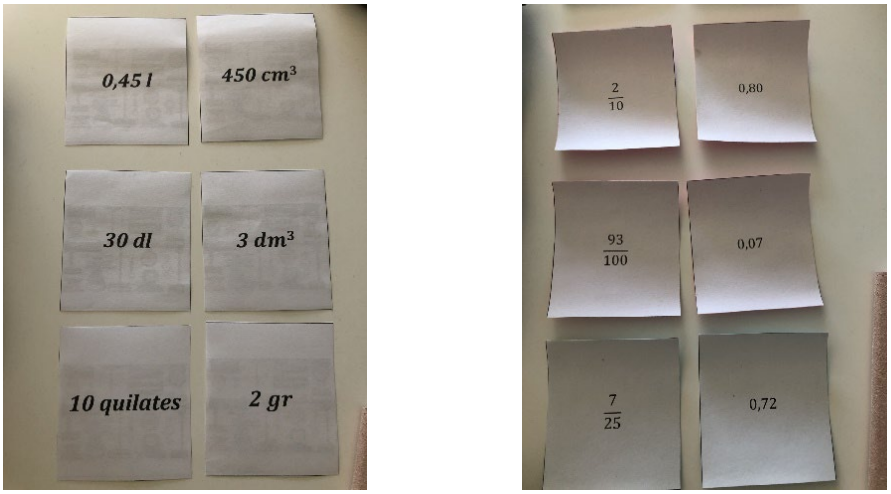


Figure 2: Examples of pairs of cards from "Mathtwins – Measurement Units" (left) and "Mathtwins – Rational Numbers" (right)

3.3 Problem Basket

This game is a treasure hunt-style game that challenges teams to solve a series of problems. The solutions to these problems lead to the discovery of a magic word. The game aims to develop problem-solving skills while exploring probability calculations in diverse situations.

Materials Needed:

- A box containing various objects and mathematical tools (ruler, calculator, etc.) accessible to all teams.
- Several identical boxes or baskets containing problems written on rolled-up pieces of paper. Each paper roll should be attached to an object.

Game instructions:

- Divide the participants into teams.
- Place the box of objects and mathematical tools in a central location.
- Distribute the problem-filled boxes or baskets among the teams.
- Explain the rules:
    - Each team must solve the problems on the paper rolls.
    - Teams can use the objects and mathematical tools in the central box to solve the problems.
    - As teams solve problems, they should arrange the paper rolls in ascending order based on their answers.
    - On each paper roll, they should write the first letter of the object attached it.
    - The word formed by the sequence of first letters is the key to the game.
    - The first team to correctly identify the magic word wins the game.

As reported in Table 1, "Problem Basket" was played in four different classes addressing three different topics. Figure 3 shows two details of the game in action.

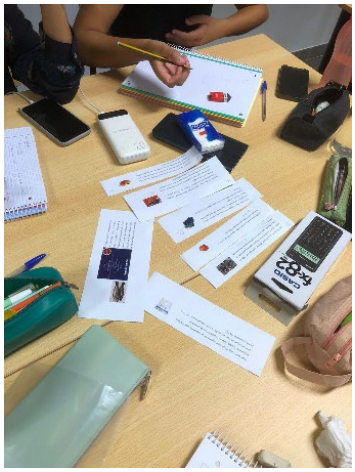


Figure 3: "Problem Basket" in action

3.4 StatPictionary

Inspired by the popular game Pictionary, "StatPictionary" focuses on descriptive data analysis. The game aims to solidify students' understanding of various types of graphs, frequency tables and sample measures as outlined in the mathematics curriculum.

Materials Needed:

- A deck of 24 cards featuring graphs/tables and questions (each card with one chart or frequency table and six numbered questions).
- Two notebooks containing (only) the graphs/tables presented on the cards.
- A white board.
- A die, a 3-minute timer, and two calculators.

Game instructions:

- Form Teams: Divide the class into two teams, ideally with 4-6 members each.
- Provide each team with a calculator and one of the notebooks.
- Teams take turns. On their turn, each team must choose a representative who:
    - draws a card and announces its number so that everyone can identify the corresponding graph/table in their notebooks. (Alternatively, project the graph onto a screen.)
    - sets the timer and rolls the die.
    - uses the whiteboard to draw a representation of the question from the card (corresponding to the number rolled on the die) in an attempt to have their team guess the question.
- If the team correctly guesses the question, they have the remaining time (at least 1 minute) to answer it.
- If their answer is correct, they earn 2 points and pass the turn to the other team.
- If their answer is incorrect, the team earns only 1 point (for guessing the question correctly), and the opportunity to answer the question passes to the other team. The other team has one minute to answer the question. If their answer is correct, they earn 1 point.
- The turn moves to the other team and the game continues as described above.
- The team with the most points after a predetermined number of rounds (equal for both teams) wins the game.

It is not allowed (i) to use words or abbreviations; (ii) to redraw the graph or any part of it; (iii) to use the values from the graph. It is allowed (i) to draw on the board; (ii) to use symbolic mathematical language; (iii) to use colours; and (iv) to use a calculator during the response phase to the questions.

Figure 4 shows the game in action.

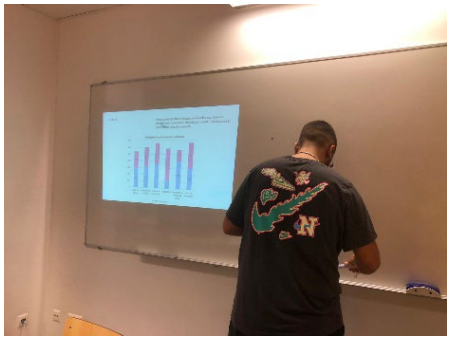


Figure 4: "StatPictionary" in action

This game demonstrates particular creativity. In closing, we would like to make some final remarks on its didactic aspects.

Learning to read: The graphs presented in the game address many different forms of data representation commonly used in statistics. In this way, students approach them in a playful and engaging way, learning to read and interpret information expressed in different ways.

Learning to ask questions: The game aims to familiarize students with the language of statistics. Players should not only answer a question (as usually happens when more traditional statistics exercises are offered), but before that, they must formulate the question correctly, encouraging them to think about the language and specific terms of this discipline, using them critically.

Effective summarizing: By experiencing the difficulty of predicting the question just by looking at the graph, students understand how an appropriate graphical representation of data allows for the transmission of a lot of information.

Let's make our own deck: After playing a few times, it may be interesting to suggest to students that they create new cards, inspired, for example, by graphs found in newspapers, and challenge them to come up with fun situations in which these graphs can be used.

4. Findings

This paper intends to investigate if the use of non-digital educational games in maths classes can contribute to increase students' motivation and involvement regarding mathematics learning.

To reach this goal, field notes and analysis of a survey were the main instruments used.

Regarding the objective stated previously – investigate if the use of game-based learning strategies contributes to increase students' motivation and involvement – several results may be reported.

4.1 Field Notes Analysis

The teacher (simultaneously the first author of this article) observed that the students thoroughly enjoyed and found the games activities to be highly enjoyable and entertaining. According to the students' feedback, this type of active and dynamic classes proved to be more appealing compared to a traditional approach. Mathematics, in particular, was perceived as a more engaging and positive subject through the use of game-based learning activities. Some participants expressed their enthusiasm, stating that the classes became much more enjoyable and interesting with this approach. These facts support a positive answer to the established objectives: evaluate if the use of game-based learning strategies contributes to making the learning process more interesting and to promoting a more positive attitude towards mathematics.

4.2 Questionnaire Analysis

To collect information about students' insights on the use of non-digital games in maths classes a questionnaire was delivered at the end of the semester. From the 12 students who took part in the activity, 9 answered the questionnaire.

Using a five-point Likert scale, students were asked if they enjoyed playing educational games in maths classes. As figure 5 shows, most students responded positively and there were no negative responses.

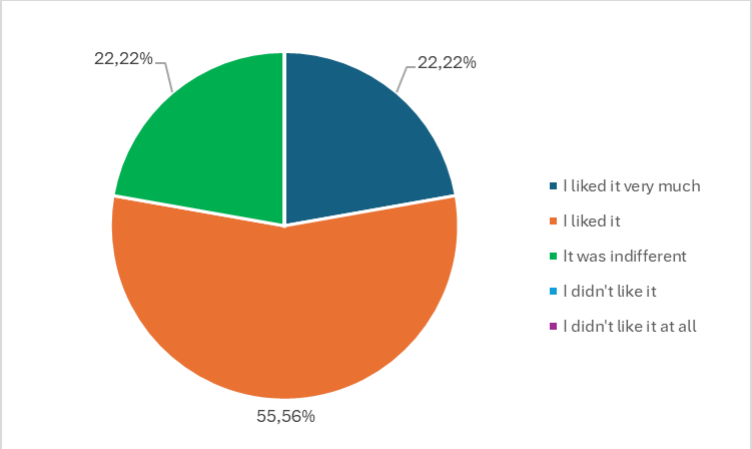


Figure 5: Pie-chart of responses to the question "Did you enjoy the educational games in maths classes?"

Through another two five-point Likert scale questions, all surveyed students considered the use of games to be relevant in the teaching and learning process of Mathematics and recommend the use of games in Mathematics classes. Regarding the questions "Did the use of games in mathematics classes help you to enjoy mathematics more?" and "Do you like the competitive aspect associated with games?", the results are identical: 55.6% of the respondents answered yes; 44.4% answered indifferent and none answered negatively.

The results regarding student game preferences are presented in Figure 6. "Problem Basket - Ratio, Proportion and Percentage" was the preferred game, followed by "SuperTmatik".

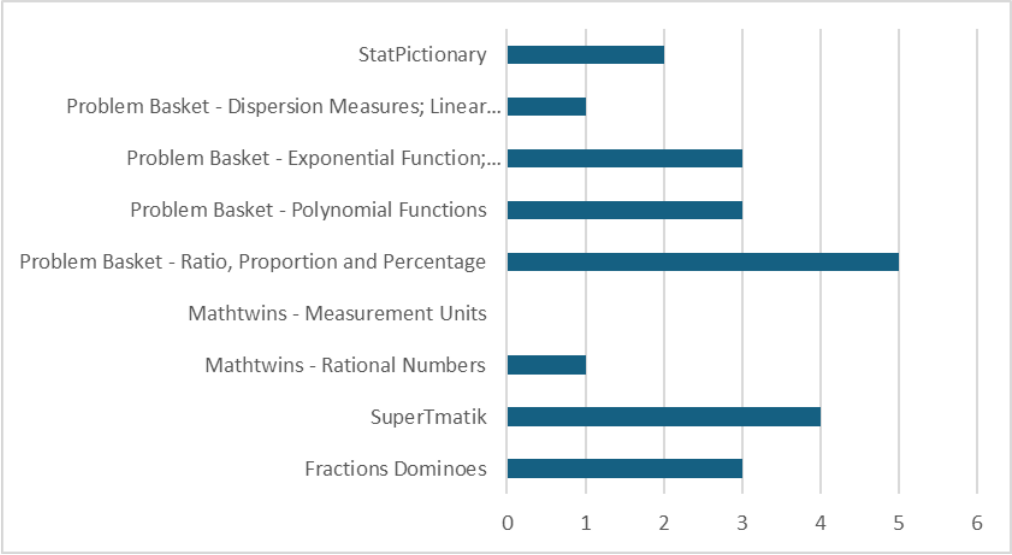


Figure 6: **Frequency table of responses to the question "Which games did you enjoy the most?"**

Students were asked to rate their agreement on a five-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree) with a set of statements concerning the use of educational games in class. The results are presented in the heatmap of Figure 7, which also includes the mean and standard deviation (sd) of the responses. We can see that, overall, the results are very positive and very few respondents disagreed with any of the statements. These results are in line with what the teacher could observe during the semester.

The use of educational games in maths classes contributed to:	1	2	3	4	5	mean	sd
making learning more interesting.	0	0	2	3	4	4,2	0,7
making learning more interactive.	0	1	1	3	4	4,1	1,1
making classes more stimulating.	0	1	1	2	5	4,2	1,2
involving the students in the learning process.	0	0	1	3	5	4,4	0,5
increasing student motivation	0	0	2	3	4	4,2	0,7
a more positive view of mathematics	0	1	2	4	2	3,8	0,9

Figure 7: Heatmap of responses related to the use of games in maths classes.

When asked what they would keep in the planning of the course for the incoming year, the most common answers were "everything" and "the games". Concerning what they would change, the respondents said they wouldn't change anything.

5. Final Remarks

The main limitation of this study is its small sample size. However, despite this limitation, the study's results demonstrate that incorporating game-based learning activities in maths classes enhances student engagement and motivation for learning by making the learning process enjoyable. These findings align with similar studies conducted by Chiang and Qin (2018), Pais and Hall (2021), Morando and Turconi (2022), Morando and Spreafico (2023). Furthermore, students perceive the game-based learning as an effective tool for promoting learning and recommend it as a pedagogical methodology.

Based on the results of this study, we conclude that the use of non-digital game-based learning activities in maths classes promotes a positive attitude towards mathematics and thus fosters motivation to learn it. Therefore, we recommend the use of non-digital game-based learning activities in classes. It is a means of helping students improve their interest in the class, their motivation for learning, and, consequently, their engagement in the learning process. Overall, it contributes to a positive environment for learning.

This study can be valuable not only for all teachers but specifically for mathematics teachers, as it provides insights into game-based learning activities. The findings can serve as a foundation for educators who aim to create a fun and engaging learning environment in their classrooms.

For future research, it is recommended to include a larger sample size to further validate the results and enhance the generalizability of the findings. Additionally, investigating other aspects related to game-based learning, such as their impact on specific learning outcomes, different subjects, or different student populations, would be beneficial for expanding our understanding of their effectiveness in education.

Acknowledgments

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