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# Mathematical Treasure Hunt at UA's Summer Academy

## Caça Matemática ao Tesouro na Academia de Verão da UA

## Búsqueda del Tesoro Matemática en la Academia de Verano de la UA

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**Abstract**

Team games offer more than just simple fun. They promote social interaction, communication, cooperation, and healthy competition. These same benefits can be harnessed in educational settings. Gamification strategies have been increasingly adopted in education. In addition to the benefits already mentioned, they also help to increase student engagement and motivation, consolidate knowledge, and improve learning outcomes (Morando and Turconi, 2022; Morando and Spreafico, 2023; Pais and Hall, 2024).
This paper presents a mathematics activity carried out during the Summer Academy at the University of Aveiro with 5th and 6th grade students, aged between 10 and 12 years, from diverse places, as well as their perceptions regarding the activity.

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The activity involved participating in a treasure hunt-style game entitled *Basket of Problems*, in which teams were challenged to solve a series of problems — in this case, mathematical ones. The solutions to these problems led to the discovery of a magic word.
To assess the participants' perceptions of the activity, a questionnaire was administered. The results indicate that the participants found the activity enjoyable, appreciated working in teams, applied their mathematical knowledge in a playful way, and felt that the activity helped them better understand the importance of mathematics. Furthermore, the results show that the participants would like to carry out activities of this kind in their regular mathematics lessons.

**Keywords:** Mathematical games; mathematics education; playful learning; gamification.

## Resumo

Os jogos de equipa oferecem mais do que simples diversão. Promovem a interação social, a comunicação, a cooperação e a competição saudável. Estes mesmos benefícios podem ser aproveitados em contexto educativo. As estratégias de gamificação têm sido cada vez mais adotadas na educação. Para além dos benefícios já referidos, permitem também aumentar o envolvimento e a motivação dos alunos, consolidar conhecimentos e melhorar os resultados da aprendizagem (Morando e Turconi, 2022; Morando e Spreafico, 2023; Pais e Hall, 2024).
Este trabalho apresenta uma atividade matemática realizada na Academia de Verão da Universidade de Aveiro com alunos do 2.º ciclo do ensino básico, crianças entre os 10 e os 12 anos oriundas de diferentes locais, bem como as suas perceções relativamente a essa atividade.
A atividade consistiu na participação num jogo, ao estilo de uma caça ao tesouro, intitulado "Cesta de Problemas", no qual as equipas foram desafiadas a resolver uma série de problemas — neste caso, matemáticos. As soluções desses problemas conduziam à descoberta de uma palavra mágica.
Para avaliar a perceção dos participantes relativamente à atividade, foi realizado um questionário. Os resultados desse questionário indicam que os participantes acharam a atividade divertida, gostaram de trabalhar em equipa, usaram os conhecimentos de matemática de forma lúdica e consideraram que a atividade contribuiu para uma melhor perceção da importância da matemática. Revelam ainda que os participantes gostariam de realizar atividades deste género nas aulas de matemática.

**Palavras-chave:** jogos matemáticos; educação matemática; aprendizagem lúdica; gamificação.

## Resumen

Los juegos en equipo ofrecen algo más que simple diversión. Fomentan la interacción social, la comunicación, la cooperación y la competencia saludable. Estos mismos beneficios pueden aprovecharse en contextos educativos. Las estrategias de gamificación se han ido adoptando cada vez más en el ámbito educativo. Además de los beneficios ya mencionados, también permiten aumentar la implicación y la motivación del alumnado, consolidar conocimientos y mejorar los resultados de aprendizaje (Morando y Turconi, 2022; Morando y Spreafico, 2023; Pais y Hall, 2024).
Este trabajo presenta una actividad matemática realizada durante la Academia de Verano de la Universidad de Aveiro con alumnado del segundo ciclo de educación básica (niños y niñas

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de entre 10 y 12 años) procedente de distintos contextos, así como sus percepciones respecto a dicha actividad.
La actividad consistió en la participación en un juego al estilo de una búsqueda del tesoro, titulado Cesta de Problemas, en el que los equipos debían resolver una serie de problemas — en este caso, de carácter matemático— cuyas soluciones conducían al descubrimiento de una palabra mágica.
Para evaluar la percepción de los participantes sobre la actividad, se aplicó un cuestionario. Los resultados de dicho cuestionario indican que los participantes consideraron la actividad divertida, disfrutaron del trabajo en equipo, utilizaron sus conocimientos matemáticos de forma lúdica y consideraron que la actividad les ayudó a comprender mejor la importancia de las matemáticas. Además, los resultados muestran que les gustaría realizar este tipo de actividades en sus clases de matemáticas.

**Palabras clave:** juegos matemáticos; educación matemática; aprendizaje lúdico; gamificación.

## Introduction

The integration of games in education has been widely recognised as an effective strategy to foster learning and student engagement. In addition to providing moments of enjoyment, team games led by the teachers encourage social interaction, promote communication, stimulate cooperation, and introduce a healthy sense of competition. Collaborative work has a positive impact in educational context and games provide a good opportunity to incorporate it (Vale and Barbosa, 2023; Fardian et al., 2024). In the educational context, these characteristics can be leveraged to enhance student motivation, consolidate knowledge, and facilitate learning in an engaging and playful manner (Morando and Turconi, 2022; Morando and Spreafico, 2023; Pais and Hall, 2024).

Playful mathematics, or mathematical learning through engaging and interactive activities, has proven to be an effective strategy to help students develop problem-solving skills, logical reasoning, and a positive attitude towards the subject. The incorporation of game-based approaches in mathematics education can transform abstract concepts into tangible and enjoyable challenges, making learning more meaningful and accessible.

While games are commonly used in formal education, their potential extends beyond the classroom, particularly in non-formal educational contexts (Eshach, 2007; Sanina et al., 2016). Non-formal learning occurs in structured settings outside the traditional school system (Eshach, 2007; Rennie et al., 2003), such as summer academies, extracurricular programmes, and educational workshops. These environments provide opportunities for students to engage with mathematical concepts in a relaxed and motivating way, free from the pressures of formal assessment, which can often hinder curiosity and exploration.

In this paper, we present and analyze the implementation of a non-digital game applied to a group of participants at the Summer Academy of the University of Aveiro in 2023.

This study aims to contribute to the discussion on the role of mathematical games in non-formal education, highlighting their potential to cultivate interest, engagement, and deeper learning experiences beyond the conventional classroom environment.

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## Methodology

In this paper we present a gamified activity to be implemented within a non-formal educational context and understand how a group of participants perceived the created activity.

The case study (Yin, 1994) was the research method used to assess the potential of the activity. This methodology was chosen for this research because it allows for an in-depth exploration of a specific, real-world educational intervention within its natural context.

The participants in this study were 20 children, aged between 10 and 12, enrolled in the University of Aveiro's summer academy, 2023.

Inquiry techniques and direct observation, were used, employing the following instruments: field notes and questionnaire. During the task implementation, the tutors adopted the participant observation technique. The questionnaire was filled out on Google Forms. The questionnaire included lists of statements and respondents were asked to rate their level of agreement using a 5-point agreement (Likert) scale.

The analysis of the results was based on observations of participants' performance and feedback collected through a questionnaire completed at the end of the activity.

## The "Problem Basket" Game

The Problem Basket is an educational game designed to enhance problem-solving skills in a collaborative and engaging manner and was created by Paola Morando and Maria Luisa Spreafico (Hall, Alvelos & Pais, 2023; Pais & Hall, 2024). The game is inspired by the scavenger hunt format, in which participants work in teams to solve a sequence of mathematical problems. The objective is to foster logical reasoning and teamwork while making mathematical problem-solving an interactive experience. The game concludes with the discovery of a "magic word," which serves as the final solution and indicates successful completion of the activity.

### Materials

The game requires the following materials:

- A central box containing various objects, accessible to all teams. For this instance, the box contained a red puzzle piece, a white ceramic object, a photograph of a stripped house, a green round sharpener, and a university campus map.
- Another central box containing mathematical tools. For this instance, the tools were several measuring tapes (3m, 5m and 20m), a 20cm ruler, a measuring jug and a bottle of water, a ball of thick thread, and scissors.
- Identical baskets or boxes, one for each team, containing problem statements written on rolled-up pieces of paper. Each roll is attached to an object. For this instance, each box had 15 problems.

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- Paper and pencils for each team.

**Game Procedure**

1. Team Formation – Participants are divided into random teams of at least three players each.
2. Material Setup – The central boxes with objects and mathematical tools are placed in a shared location, accessible to all teams.
3. Problem Distribution – Each team receives a basket or box containing the mathematical problems.

**Game Rules**

- Teams must solve all problems in their baskets.
- They are allowed to use the central boxes to assist in problem-solving.
- As teams obtain numeric solutions, they must arrange the paper rolls in ascending order based on the corresponding answers.
- Each paper roll is attached to an object, and teams must write down the first letter of the corresponding object.
- The sequence of first letters forms a word, which serves as the final answer.
- The first team to correctly identify the magic word wins the game.

**Game Tips**

The number of problems should not be too small, as this could allow teams to determine the magic word simply by identifying the first letter of the attached objects and arranging them in the correct order. Additionally, the objects should not be too obvious to name, ensuring that students focus on solving the mathematical problems rather than easily deducing the correct letter sequence. For example, if one of the objects is a gummy in the shape of a fried egg, should the first letter be G for gummy or E for egg?

The problems should be diverse in multiple aspects. Some should be easy to solve, while others should be more challenging. Some may require only reasoning, paper, and pencil, whereas others might involve fieldwork, taking students outdoors (or at least moving around the room), making measurements and estimations. Certain problems may incorporate cultural or historical elements, while others may focus on scientific concepts. Some may be contextualized within the surroundings, whereas others might be set in an imaginary scenario.

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**Educational Value**

The Problem Basket activity was designed to foster logical reasoning, collaboration, and engagement through playful problem-solving. It combines elements of gamification and experiential learning to promote positive attitudes toward mathematics, particularly in non-formal educational settings.

## Activity Description and Analysis

The Problem Basket was played on July 12th 2023, from 15h00 Pm to 17:00 PM, at the University of Aveiro by 20 children registered in the Summer School. Students were divided into six groups of three or four students each.

The first two authors of this paper were responsible for conducting the activity. They began by explaining the game rules and procedures to the students. Afterward, they distributed one basket to each group and provided only scaffolding support, allowing the students to engage independently in the activity. Figure 1 presents two photos: one displaying the basket containing the six problem baskets, and another capturing a moment during the unfolding of the activity.

Figure 1. Problem Basket – The room; the basket; the unfolding of the activity.

Each basket contained 15 rolls of paper, each with a problem statement and an attached object.

The initial letters of the objects, when arranged in the correct order based on the problem solutions, form the magic word "Extraordinary" (*Extraordinários* in Portuguese). The word was chosen to reinforce the idea that problem-solving can be both fun and rewarding.

During the game, a high level of interaction and collaboration was observed among the participants, who actively engaged in discussing strategies and solutions to solve the problems.

Next, we present the list of problems contained in the basket, providing an answer and a worked-out solution for each. We also identify the objects attached to the rolls, offering examples for future replication or adaptation of the activity.

We examine students' solutions, highlighting both their creative approaches and common mistakes and misconceptions.

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The problems are listed in increasing order of their solutions, which also determines the correct order for forming the magic word.

*Problem 1*

*"Inside the box of objects, there is an image of a red puzzle piece. Calculate its perimeter and express the result in decimeters."*

The puzzle piece, shown in Figure 2 (left), was inscribed within a 10 × 10 cm square, and its perimeter was measured at 4.6 dm. Students had to be creative to measure the perimeter. All groups used a thread to follow the contour of the puzzle piece to determine its perimeter.

The object attached to this problem was a star (***E****strela* in Portuguese).

Figure 2. Puzzle piece (left); Stairway to Heaven by Volker Schnuttgen (center)
and photo of a student solving Problem 3 (right)

*Problem 2*

"*Outside the department of Mathematics building, on the northwest side, there is a sculpture called «Stairway to Heaven.»*
- *What is the name of the sculptor?*
- *How many steps does the staircase have?"*

The sculpture (Figure 2, center) was created by Volker Schnüttgen in 1991 and has six steps. However, some students counted seven steps considering the starting level as a step.

When designing problem-solving activities, it is important to anticipate different interpretations and ensure that alternative valid answers do not disrupt the activity. In this case, both six and seven are acceptable answers and do not affect the game's outcome.

The object attached to this problem was a chessboard image (chess = ***X****adrez* in Portuguese).

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*Problem 3*

*“In the box of objects, look for a round sharpener and a sheet with a photograph of a house from Costa Nova. Determine how many complete turns the sharpener must make to complete the perimeter of the image.”*

Figure 2 (right) shows a student solving this problem. In general, students measured the perimeter by rolling the sharpener around the picture. However, this method is prone to error due to inconsistent alignment leading several groups to underestimate the real value.

An alternative approach would be to:

1. Measure the perimeter of the house using a measuring tape or ruler.
2. Determine the perimeter of the circular sharpener by measuring its diameter.
3. Divide the perimeter of the house by the sharpener’s perimeter to obtain the number of complete turns required.

Using this method, the solution indicates that the perimeter is approximately 8.3 times the sharpener’s perimeter leading to the answer eight.

The object attached to this problem was bottle lid (lid = ***T****ampa* in Portuguese).

*Problem 4*

*“At night, the snails gather in the semi-circular lake located in the central area of the UA campus. The lake is marked on the campus map found inside the box of objects. What is the total area of the lake (including its surrounding walls) in square meters?”*

Figure 3 shows the lake involved in this problem. The correct answer is 9,8 square meters. To solve this, students had to apply their knowledge of circular areas and use π (pi) in their calculations. The diameter of the lake is approximately 5m thus the area of the lake is $\frac{1}{2} \times \pi \times 2{,}5^2 \approx 9{,}8 \text{ m}^2$. Students did not find this problem difficult.

The object attached to this problem was a bottle cork (***R****olha* in Portuguese).

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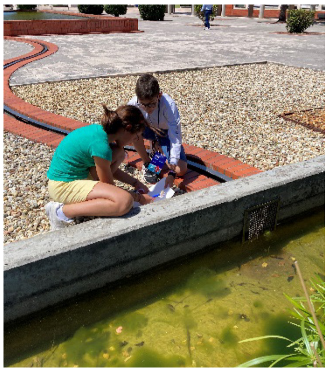

Figure 3. Semi-circular lake in the campus and students making calculations next to it. (Photo on the left: https://maissuperior.com/2019/06/18/universidade-de-aveiro-um-campus-de-oportunidades-2/)

*Problem 5*

*"Determine the height, in meters, of the northwest facade of the DMat building, as shown in the image."*

To solve this problem, students had to go outside and use estimation techniques after taking some measurements. The correct answer is approximately 11 meters and most groups did a good estimate of the height. The students measured the distance between two bars forming the grid that covers the façade in that area and multiplied it by the number of intervals between the bars in the grid.

The object attached to this problem was a plastic ring (***A**nel* in Portuguese).

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*Problem 6*

*"At the beginning of last year, the Snails Today magazine ran an advertising campaign for a highly nutritious variety of lettuce, which led to a 30% weight increase in its snail readers over six months. The magazine then launched an advertising campaign for a special snail diet, resulting in a 10% weight reduction over the rest of the year.*

*Calculate the overall percentage change in the snails' weight over the entire year."*

This was one of the most difficult problems in the basket. A correct answer may be obtained as follows:

Let's assume the initial weight of a snail is 100 units (for simplicity).

Step 1: 30% Increase in Weight

After a 30% increase, the new weight is: 100+(100×0.30)=100+30=130

Step 2: 10% Decrease in Weight

After a 10% reduction, the weight is: 130-(130×0.10)=130-13=117130 - (130 × 0.10) = 130 - 13 = 117130-(130×0.10)=130-13=117

Step 3: Overall Percentage Change

The overall percentage change is calculated as:

$$\frac{\text{Final Weight} - \text{Initial Weight}}{\text{Initial Weight}} \times 100 = \frac{117 - 100}{100} \times 100 = \frac{17}{100} \times 100 = 17\%$$

Several groups did not solve this problem correctly. They tended to overlook the fact that the percentages apply to different quantities, leading them to incorrectly calculate the overall change as 20% by simply subtracting 30% 10%. This misconception makes the game more challenging, as the next problem's solution falls between 17% and 20%, increasing the likelihood of ordering errors.

The object attached to this problem was a gummy egg (***O**vo* in Portuguese).

*Problem 7*

*"In a class, 72% of students have a pet snail. On days when they have a Math test, 25% of these students bring their pet snail to school for good luck.*

*Calculate the percentage of students in the class who bring a pet snail to school on Math test days."*

The percentage of students in the class who bring a pet snail to school on Math test days is 18%, which is obtained by calculating 25% of 72%. Although significantly easier than the previous problem, students still found this one challenging, as half of the groups did not arrive at the correct percentage.

The object attached to this problem was a candy (***R**ebuçado* in Portuguese).

*Problem 8*

*"On the planet Isanilop, one-sixth of the snails have three noses, one-third have four noses, and the rest have five noses. Knowing that there are 108 snails with five noses on the planet:*

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*How many snails have three noses?"*

Using the given information we see that $\frac{1}{6}+\frac{1}{3}+\text{Fraction of snails with 5 noses}=1$ leading to $1-\frac{1}{6}-\frac{1}{3}=\frac{1}{2}$ being the Fraction of snails with 5 noses. One possible way to proceed is to determine the total number of snails, 2×108=216, and obtain the number of snails with three noses, 216÷6=36. As with the previous two problems, several groups were unable to reach the correct solution. Fractions and percentages remain challenging for most students.

The object attached to this problem was a dice (***D****ado* in Portuguese).

*Problem 9*

*"Filipe loves rare animals. He has collected 70 animals, each with either three or five legs. He wants to buy hats for the five-legged animals but cannot remember how many of them there are. However, he recalls that last Christmas he bought 145 pairs of socks, which were enough for all the legs of the animals in his collection.*

*How many hats does he need to buy?"*

The correct answer to this problem is 40. This is not a simple problem for a 12-year-old child, and indeed, several groups did not arrive at the correct solution. One way to obtain the solution without solving equations is as follows.

The total number of legs is in the collection is 145×2=290. So, all 70 animals together have 290 legs. If all the animals had three legs, that would be 70×3=210 legs. But that's not enough — we need 290 legs! That means some animals must have five legs instead of three.

Every time we swap a three-legged animal for a five-legged animal, we add two extra legs. We need 80 more legs to reach 290 (since 290 - 210 = 80). Since each five-legged animal adds 2 extra legs compared to a three-legged one, we divide 80÷2=40. So, 40 animals have five legs, and the remaining 30 animals have three legs. Since Filipe needs to buy one hat per five-legged animal, he needs 40 hats.

The object attached to this problem was an incense stick (***I****ncenso* in Portuguese).

*Problem 10*

*"Determine the diameter, in decimeters, of the well located in the central area of the UA campus. The well is marked on the campus map inside the box of objects."*

The well has an approximate diameter of 47 dm. Due to its large size and the presence of a hanging iron structure in the middle, measuring the diameter directly is challenging. Some groups determined the diameter by measuring the perimeter and dividing by π, while others attempted to measure it directly. A couple of groups successfully took the measurements but failed to convert them to decimeters. Figure 4 shows photos of two groups performing measurements using each of these approaches.

The object attached to this problem was a walnut (***N****oz* in Portuguese).

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Figure 4. Students taking measures of the well in the campus.

*Problem 11*

*"Eduardo arranged to meet his friends at 5:00 PM at the gym for a workout. The travel details are as follows:*

- *He takes 10 minutes to walk from his house to the nearest metro station.*
- *The metro takes 45 minutes.*
- *From the arrival metro station to the gym, he walks for another 5 minutes.*
- *The metro passes every 10 minutes.*

*What is the minimum number of minutes Eduardo should leave his house in advance to ensure he is not late for the meeting?"*

To ensure he arrives at the gym by 5:00 PM, Eduardo must leave his house 70 minutes in advance. The first three time intervals mentioned in the text are fixed and add up to 60 minutes. The final time interval is variable and, in the worst-case scenario, can take up to 10 minutes if a metro has just departed when Eduardo arrives at the station. Therefore, in the worst-case scenario, Eduardo needs 70 minutes to reach the gym.

Several groups arrived at the correct solution, but some appeared to have misunderstood the impact of the variable waiting time for the train. As a result, some groups answered 60 minutes instead of 70 minutes.

The object attached to this problem was a hazelnut (***A****velã* in Portuguese).

*Problem 12*

*"At the main entrance of the DMat building (still outside), there is a bench with a seat made of white limestone.*

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*Determine the volume of this stone and express the result in cubic decimeters (dm³)."*

The stone has a cuboid shape, with dimensions of 155 cm, 50 cm, and 11.5 cm (see Figure 5). Thus, its volume is calculated as $15.5 \times 5 \times 1.15 \approx 89 dm^3$. Most groups applied the correct reasoning for this problem, but three did not convert the measurements into cubic centimeters correctly. Additionally, a few groups did not take accurate measurements.

The object attached to this problem was a piece of plastic net (***R**ede* in Portuguese).

Figure 5. Photos of students making measurements of the limestone seat.

*Problem 13*

*"Gonçalo loves eating snails. He wants to cook five different dishes, each in a separate pot, using a stove that has only two burners. The required cooking times for each dish are:*

- *Snails with Garlic and Coriander: 20 minutes*
- *Snails with Green Sauce: 45 minutes*
- *Marinated Snails: 50 minutes*
- *Plain Boiled Snails: 15 minutes*
- *Snail Curry: 55 minutes*

*What is the minimum time required (in minutes) to cook all five dishes?"*

To solve this puzzle, students need to think strategically. The minimum cooking time is 95 minutes, which can be achieved with the following distribution of cooking times. Start by placing the two longest-cooking dishes on the burners first, then continue by adding the third longest dish to the burner that finishes first. Here is a possible scheduling scheme:

- Burner 1: *Marinated Snails* (50 min); *Snails with Green Sauce* (45 min);
- Burner 2: *Snail Curry* (55 min) *Snails with Garlic and Coriander* (20 min); *Plain Boiled Snails* (15 min)

Note that 95 min is the minimum possible time since the average cooking time per burner is 92,5 min and all cooking times are multiples of 5.

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Most groups found this problem difficult, with only two managing to obtain the correct answer. The object attached to this problem was a lighter (***I**squeiro* in Portuguese).

*Problem 14*

*"On the planet Isanilop, a popular drink is made from water and snail slime.*

- *In the light version, every 100 litres of the drink contains 10 litres of slime, with the rest being water.*
- *In the strong version, every 100 litres contains 40 litres of slime, with the rest being water.*
- *There is a 200-litre tank of the light version of the drink.*

*How many litres of snail slime should be added to the tank to convert the drink into the strong version?"*

This problem is one of the most difficult ones in the list and only two groups provided the right solution which is 100 litres of slime. We are given a 200-litre tank of a drink made from water and snail slime, and we need to increase the slime concentration to turn it into the strong version. We need to add the necessary slime considering the existing water in the tank. One possible reasoning is as follows.

First, understand the two versions:

- Light Version: 10% slime, meaning 10 litres of slime per 100 litres of drink.
- Strong Version: 40% slime, meaning 40 litres of slime per 100 litres of drink.

Second, find the current amount of water and slime. Since the light version contains 10% slime, the 200-litre tank currently has 200×0.10=20 litres of slime and 200-20=180 litres of water.

Third, determine the required amount of slime. In the strong version, the drink should consist of 40% slime and 60% water. Since there are 180 litres of water, which corresponds to 60% of the total drink, we can calculate that each 10% of the drink equals 180÷6=30 litres. Thus, 40% of the drink amounts to 30×4=120 litres. This means that the drink must have 120 litres of slime.

Finally, calculate the additional slime needed. Since 120 litres of slime are required and 20 litres are already present, we need to add 120−20=100 litres of slime.

The object attached to this problem was a plastic eye (***O**lho* in Portuguese).

*Problem 15*

*"Calculate the volume of the white ceramic piece found inside the box of objects, expressing the result in cubic centimeters (cm³)."*

To determine the volume of the white ceramic piece, students should use the water displacement method. This method is based on Archimedes' principle, which states that when an object

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is submerged in water, it displaces a volume of water equal to its own volume. Figure 6 shows the ceramic piece and the measuring jug provided to the students. Since the measuring jug has limited precision, the result should be between 100 $cm^3$ and 120 $cm^3$.

The object attached to this problem was a travel-size soap (***S****abonete* in Portuguese).

Figure 6. Ceramic piece and measuring jug used in the last problem.

Overall, we believe that this Problem Basket presented a well-curated set of challenges, achieving a balance between hands-on activities and reasoning tasks, easy and difficult problems, and real-world scenarios and imaginative (fun) setups. When designing the problem statements, we anticipated that only Problems 6, 9, and 14 would be challenging for some students. However, an analysis of the groups' responses revealed that students also encountered difficulties with Problems 7, 8, and 13. The unexpected difficulty encountered in these additional problems highlights the need for more targeted reinforcement of these mathematical concepts.

Most problems involving measurements of length, area, or volume were intentionally designed to require unit conversions between submultiples of the meter. As expected, several groups struggled with these conversions.

Future implementations of the activity could include hints, scaffolding, or preliminary exercises to better prepare students for the challenges they struggled with.

We conclude this section with Figure 7, which illustrates the final steps of the challenge — arranging the papers in the correct order to reveal the magic word.

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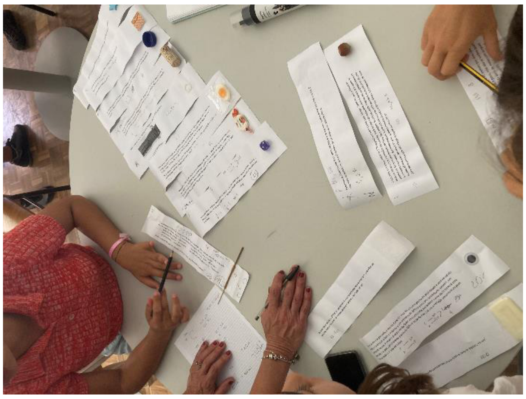
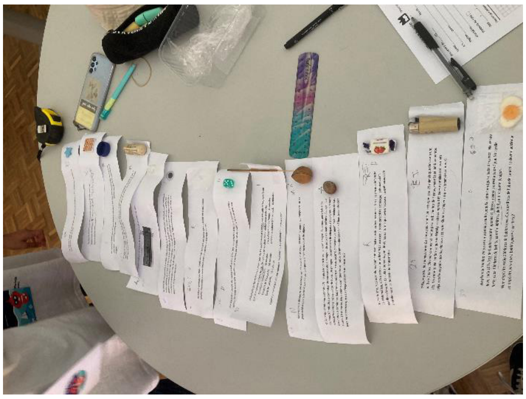
Figure 7. Final stages of the game.

All teams were actively engaged in the activity although not all managed to complete it successfully within the time limit. Some teams were unable to discover the magic word due to errors in solving the problems, which led to incorrect numerical answers and, consequently, to an incorrect ordering of the associated letters. In other cases, teams struggled to correctly identify the object associated with a given problem, or simply ran out of time before completing all tasks. However, the structure of the game allows for flexibility and strategic reasoning: even if one or more letters are out of order—or even incorrect—teams can still attempt to reconstruct the word by testing different letter arrangements and applying logical inference. This aspect adds an additional layer of problem-solving, encouraging players to reflect critically on their results and to use partial information creatively in pursuit of the final solution.

Every student received a participation prize (a notebook and a pencil) as a reward for their effort and engagement. Additionally, the first team to correctly identify the magic word was awarded a special prize — an illustrated children's book featuring mathematical stories and activities for each child.

The use of rewards ensures that all students feel recognized for their efforts, regardless of their final ranking, while also maintaining a healthy competitive element that drives engagement and deeper learning.

## Results: Questionnaire Analysis

The paper contains the result of a non-interventional study, i.e. a survey (qualitative questionnaires), which does not need ethical approval. The completion of the questionnaire was voluntary and anonymous; moreover the university is the guarantor of data processing and privacy for activities performed in summer academy context.

The questionnaire was administered via Google Forms, but some limitations arose, as not all participants had mobile phones or internet access. As a result, there were only 16 respondents—11 girls and 5 boys—aged between 10 and 12 years, as shown in Figure 8.

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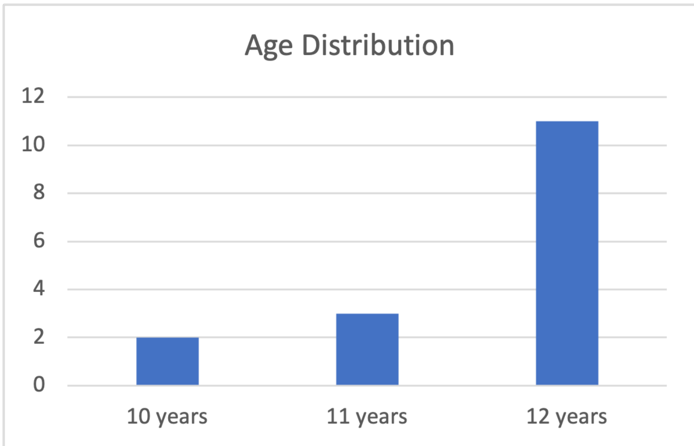


Figure 8. Age distribution of respondents.

Participants were asked whether they enjoyed the activity using a 5-point Likert scale. The responses are shown in Figure 9, and from the results we may conclude that 81.3% responded positively, 12.5% found it indifferent, and only 6.3% (1 student) stated they did not like it.

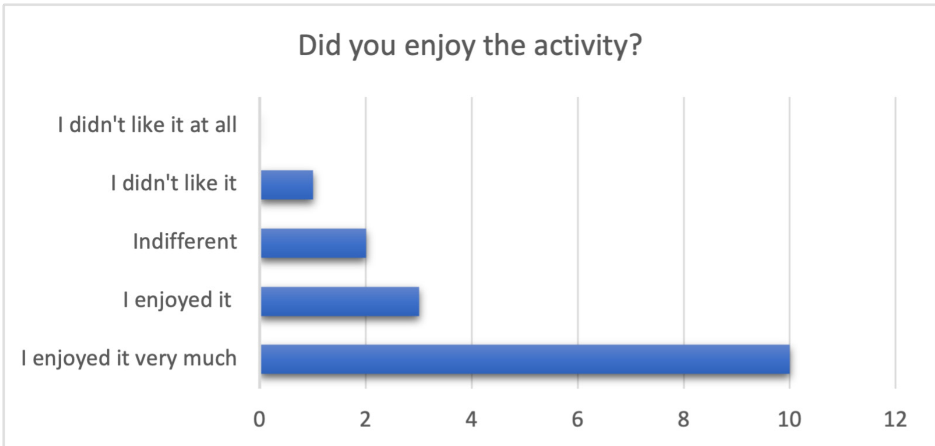


Figure 9. Frequency graph of responses.

Participants were asked to rate their agreement with two sets of statements using a 5-point Likert scale (1 – total disagreement; 5 – total agreement). The results are summarized in the heatmaps in Figures 10 and 11, along with the mean and standard deviation of the responses.

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| | 1 | 2 | 3 | 4 | 5 | mean | Std. Dev. |
|---|---|---|---|---|---|---|---|
| **This activity…** | | | | | | | |
| was fun | 0 | 1 | 1 | 5 | 9 | 4,38 | 0,78 |
| was very difficult | 0 | 1 | 6 | 7 | 2 | 3,63 | 0,65 |
| helped me enjoy Math more | 1 | 1 | 0 | 7 | 7 | 4,13 | 1,32 |
| helped me better understand the importance of Math | 0 | 2 | 1 | 3 | 10 | 4,31 | 1,16 |
| only served as a distraction, nothing else | 9 | 4 | 2 | 1 | 0 | 1,69 | 0,90 |
| had an appropriate duration | 0 | 0 | 1 | 7 | 8 | 4,44 | 0,40 |
| was well organized | 0 | 0 | 1 | 7 | 7 | 4,13 | 0,48 |

Figure 10. Heatmap of responses to the first set of statements.

The heatmap in Figure 10 provides valuable insights into students' overall perceptions of the activity's organization, difficulty, and engagement. The highest-rated statement, "The activity was well-organized" (mean = 4,44), suggests that students found the structure and implementation smooth and efficient. Similarly, "The activity had an appropriate duration" (mean = 4,13) indicates that most students were satisfied with the allocated time.

The statement "The activity was very difficult" received a mean score of 3,63, suggesting that while some students found the challenges manageable, others struggled. However, this score, being close to the middle of the scale, indicates that the difficulty level was balanced, ensuring engagement without causing excessive frustration. The lowest-rated statement, "The activity only served as a distraction, nothing else" (mean = 1,69), confirms that students viewed the activity as meaningful rather than a mere pastime.

| | 1 | 2 | 3 | 4 | 5 | mean | Std. Dev. |
|---|---|---|---|---|---|---|---|
| **In this activity…** | | | | | | | |
| I used my Math knowledge in a fun way | 0 | 1 | 2 | 3 | 10 | 4,38 | 0,92 |
| I was able to remember what I learned in Math classes | 0 | 2 | 3 | 5 | 6 | 3,94 | 1,13 |
| I managed to relate Math to everyday topics | 0 | 1 | 2 | 7 | 5 | 3,81 | 0,85 |
| I enjoyed solving problems as part of a team | 0 | 1 | 2 | 5 | 7 | 3,94 | 0,90 |

Figure 11. Heatmap of responses to the second set of statements.

The heatmap in Figure 11 highlights students' perceptions of the activity, particularly its role in engaging their mathematical knowledge. The highest-rated statement, "I used my Math knowledge in a fun way" (4,38), suggests that most students found the activity enjoyable and interactive. However, the statement "I was able to remember what I learned in Math classes" (3,94) and "I managed to relate Math to everyday topics" (3,81) indicate that while some students made strong connections to prior learning, others found the problems more abstract.

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The statement "I enjoyed solving problems as part of a team" (3,94) reflects a generally positive view of collaboration.

Participants were also asked to select the problems they enjoyed solving the most, and their preferences were summarized in the frequency chart in Figure 12.

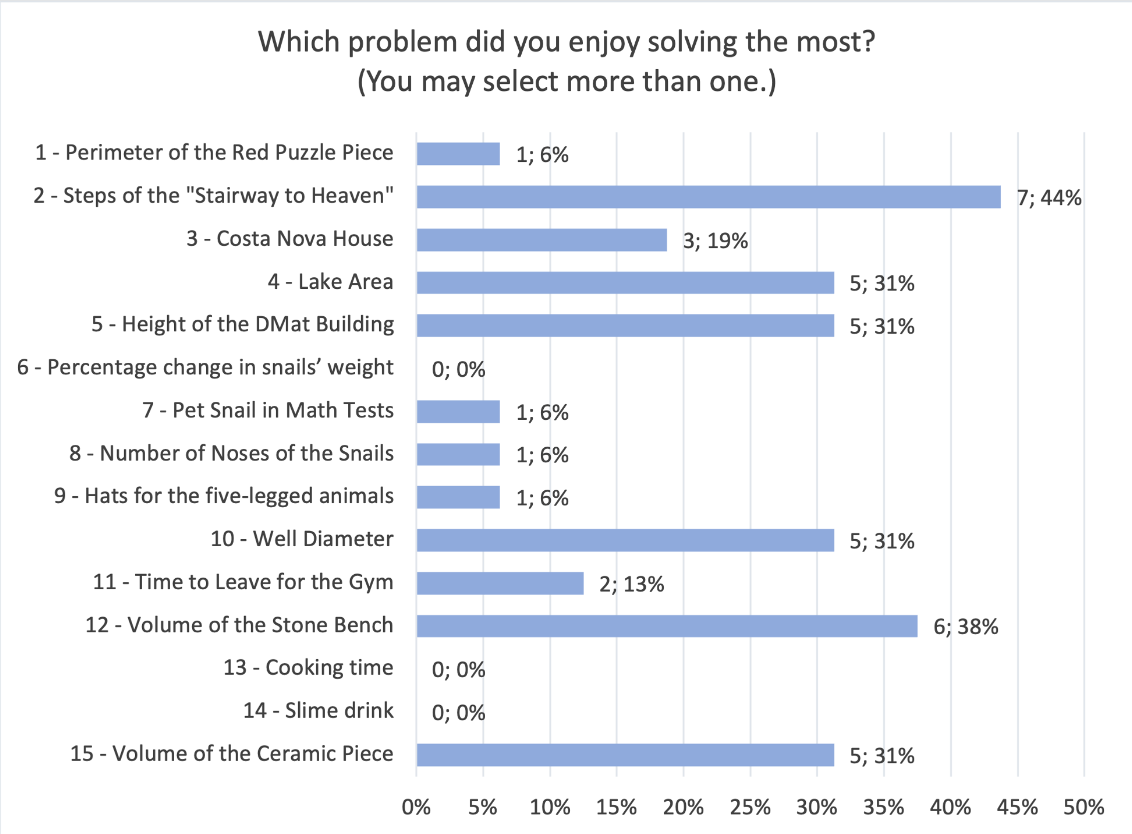


Figure 12. Frequency distribution of preferred problems

Figure 12 reveals that the most frequently chosen problems were those involving fieldwork—measuring, hands-on procedures, or physical interaction with objects.

Additionally, the most difficult problems (Problems 6 to 9, 13 and 14) were scarcely selected, with none or at most one choice each.

These results suggest that when a problem is perceived as too challenging, it diminishes students' enjoyment. Additionally, the findings indicate that students prefer hands-on, interactive activities over purely theoretical reasoning, reinforcing the importance of experiential learning in mathematics education.

Students were asked if they considered the subject of mathematics to be important: 87.5% responded "very important" and 12.5% "important". No student considered it "of little importance".

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When asked if they would like to participate in similar activities in their math classes and if they found the locations where the tasks were carried out to have been well chosen, 93.8% answered "yes" and only 6,3% (1 student) answered "no," as can be seen in Figure 13.

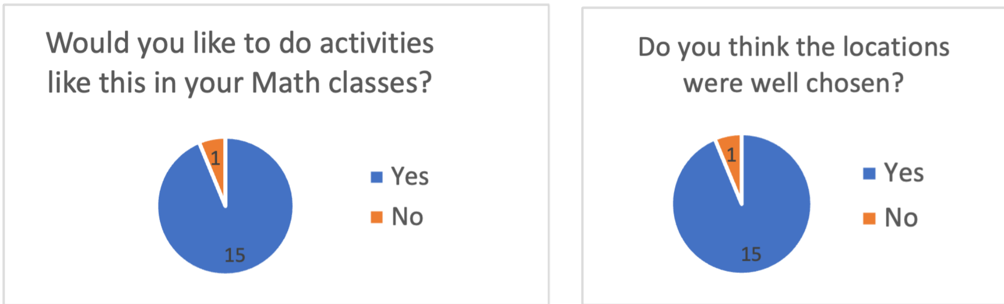


Figure 13. Pie charts of responses.

Overall, the results suggest that the Problem Basket activity was well-received, particularly in making math more engaging. Furthermore, the results demonstrate that students found the activity well-structured, appropriately challenging, and engaging. The difficulty level appears to have been well-calibrated, ensuring that students remained motivated and involved while still being challenged.

## Conclusions

The findings of this study underscore the efficacy of the Problem Basket activity in enhancing students' engagement and positive attitudes toward mathematics. The preference for hands-on, interactive problems over purely theoretical ones further highlights the value of experiential learning. The overwhelmingly positive response to the importance of mathematics and the desire to participate in similar activities in the future suggest that integrating such approaches into math education can significantly improve students' interest and appreciation for the subject.

The data reveal that strategically designed activities like the Problem Basket can make math more accessible and enjoyable, thereby fostering a deeper understanding and enthusiasm among students. This evidence supports the continued use of educational games and interactive methods to enrich the teaching and learning process in mathematics. By creating a learning environment that encourages active participation and practical application, students are more likely to develop a lasting interest in mathematics and a deeper understanding of its principles.

Additionally, the study indicates that when problems are perceived as overly challenging, students' enjoyment diminishes. This finding emphasizes the importance of calibrating the difficulty level of activities to ensure that they remain engaging without becoming discouraging. The balance between challenge and accessibility appears to be crucial in maintaining students' motivation and involvement in mathematical tasks.

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Furthermore, the positive reception of the Problem Basket activity, including the high percentage of students who found the locations well-chosen and expressed interest in similar future activities, suggests that the structure and context of educational activities significantly impact their effectiveness. The integration of experiential learning and hands-on activities not only makes mathematics more relatable but also helps students appreciate its practical applications.

The study also highlights the role of educational games in promoting a positive attitude toward mathematics. Games and interactive methods provide a dynamic and engaging way to explore mathematical concepts, making learning more enjoyable and effective (Debrenti, 2024; Erşen and Ergül, 2022; Marange and Adendorff, 2021). By incorporating these methods into the teaching process, educators can create a more stimulating and supportive learning environment that fosters curiosity and enthusiasm for mathematics.

In conclusion, the findings of this study advocate for the continued use of experiential learning, educational games, and interactive methods in mathematics education. These approaches not only enhance student engagement but also contribute to a more profound understanding and appreciation of mathematics. By carefully designing activities that balance challenge and accessibility, educators can ensure that students remain motivated and involved, leading to better learning outcomes and a positive attitude toward the subject.

## Authors contributions

Conceptualization: Paula Oliveira, Andreia Hall, Sónia Pais, Paola Morando and Maria Spreafico; Methodology: Sónia Pais; Software: N/A; Validation: N/A; Formal analysis: Sónia Pais and Andreia Hall; Investigation: Paula Oliveira, Andreia Hall and Sónia Pais; Resources: Paula Oliveira, Andreia Hall, Paola Morando and Maria Spreafico; Data curation: Sónia Pais; Writing – original draft: Paula Oliveira, Andreia Hall and Sónia Pais; Writing – review and editing: : Paula Oliveira, Andreia Hall, Sónia Pais, Paola Morando and Maria Spreafico; Visualization: Paula Oliveira, Andreia Hall and Sónia Pais; Supervision: N/A; Project administration: N/A; Funding acquisition: N/A.

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