desenvolvimento curricular e didática

Conferência Internacional Joga-Mate

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

Pi Museum: an Educational Escape Room for Learning Mathematics

Museu do Pi: um Escape Room Educativo para Aprendizagem da Matemática

Museo de Pi: un Escape Room Educativo para el Aprendizaje de las Matemáticas

Irene Araújo
Escola Básica de Gouveia
Departamento de Matemática, Universidade de Aveiro
irenelaraujo@gmail.com

Sónia Pais
CITUR, Centro de Investigação em Turismo, Instituto Politécnico de Leiria
CIDMA, Centro de Investigação e Desenvolvimento em Matemática e Aplicações, Universidade de Aveiro
sonia.i.pais@ipleiria.pt
https://orcid.org/0000-0003-2834-2267

Andreia Hall
CIDMA, Centro de Investigação e Desenvolvimento em Matemática e Aplicações, Universidade de Aveiro
andreia.hall@ua.pt
https://orcid.org/0000-0001-8759-7927

Abstract

This paper presents the implementation of a virtual educational escape room (EER) titled “Pi Museum”, designed to promote interactive mathematics learning within the context of the International Day of Mathematics, celebrated on March 14th, also known as Pi Day.
The EER was developed on the Genially platform and applied to 6th-grade classes in a Portuguese school as a formative assessment tool. The escape room’s theme was structured to reinforce students’ knowledge of the number Pi, its history, and applications, as well as to consolidate concepts of perimeter, area, and volume, always involving the number Pi whenever possible.
The experience showed that gamification facilitates knowledge acquisition, improves student motivation, and fosters teamwork. The results indicate that students felt engaged and motivated, rating the experience as enriching and fun. The methodology used was based on solving interactive mathematical challenges, promoting an innovative approach to teaching. The EER also offered the possibility of developing transversal skills, which are fundamental for students’ overall development.

Keywords: Educational escape room; gamification; mathematics essential learnings; pi (π); pedagogical innovation.

desenvolvimento curricular e didática

Conferência Internacional Joga-Mate

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

Resumo

Este artigo apresenta a implementação de um *escape room* educativo (ERE) virtual intitulado "Museu do Pi", concebido para promover a aprendizagem interativa da Matemática no contexto das comemorações do dia Internacional da Matemática, 14 de março, também celebrado como dia do Pi. O ERE foi desenvolvido na plataforma Genially e aplicado a turmas do 6.º ano de uma escola básica em Portugal como uma ferramenta de avaliação formativa. O tema do *escape room* foi estruturado para reforçar o conhecimento dos alunos sobre o número Pi, sua história e aplicações, bem como para consolidar conceitos de perímetros, áreas e volumes, sempre que possível envolvendo o número Pi.
A experiência mostrou que a gamificação facilita a aquisição de conhecimentos, melhora a motivação dos alunos e fomenta o trabalho em equipa. Os resultados indicam que os alunos se sentiram envolvidos e motivados, classificando a experiência como enriquecedora e divertida. A metodologia utilizada baseou-se na resolução de desafios matemáticos interativos, promovendo uma abordagem inovadora ao ensino. O ERE trouxe também a possibilidade de desenvolvimento de competências transversais, tão fundamentais na formação integral dos alunos.

Palavras-chave: *Escape room* educativo; gamificação; aprendizagens essenciais de matemática; pi (π); inovação pedagógica.

Resumen

Este artículo presenta la implementación de un escape room educativo (ERE) virtual titulado "Museo de Pi", diseñado para promover el aprendizaje interactivo de las Matemáticas en el contexto de la celebración del Día Internacional de las Matemáticas, el 14 de marzo, también conocido como el Día de Pi.
El ERE fue desarrollado en la plataforma Genially y aplicado a clases de 6º grado de una escuela en Portugal como herramienta de evaluación formativa. La temática del escape room fue estructurada para reforzar el conocimiento de los estudiantes sobre el número Pi, su historia y aplicaciones, así como para consolidar conceptos de perímetro, área y volumen, siempre que fuera posible involucrando el número Pi.
La experiencia demostró que la gamificación facilita la adquisición de conocimientos, mejora la motivación de los estudiantes y fomenta el trabajo en equipo. Los resultados indican que los estudiantes se sintieron involucrados y motivados, calificando la experiencia como enriquecedora y divertida. La metodología utilizada se basó en la resolución de desafíos matemáticos interactivos, promoviendo un enfoque innovador de la enseñanza. El ERE también brindó la posibilidad de desarrollar habilidades transversales, tan fundamentales para la formación integral de los estudiantes.

Palabras clave: Escape room educativo; gamificación; aprendizajes esenciales de matemáticas; pi (π); Innovación pedagógica.

Introduction

Mathematics is a fundamental subject that plays a crucial role in the development of critical thinking and problem-solving skills (Boaler, 2022). However, many students find mathematics to be a difficult and uninteresting subject (Attard, 2013). Several factors contribute to students' percep-

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

tion of mathematics as a difficult and unappealing subject. One significant issue is the traditional approach to teaching mathematics, which often emphasises memorisation and procedural fluency over conceptual understanding (National Research Council, 2002; National Council of Teachers of Mathematics, 2020). This can lead to a lack of motivation and engagement in mathematics learning.

One way to address this challenge is to use innovative teaching methods that make mathematics more engaging and relevant to students' lives. Within the many new methods that have been used in the past decades, gamification resources deserve special attention. Gamification refers to the incorporation of game elements in non-game contexts to enhance user engagement and motivation (Deterding et al., 2011). Gamification is a powerful tool that can help students learn Mathematics more effectively within a creative and dynamic environment (Gutiérrez-Fallas, 2024; Hall et al., 2024; Morando & Turconi, 2022; Pais et al., 2024; Santos et al. 2021). In mathematics education, gamification has been used to make abstract concepts more tangible and accessible. Digital tools such as Kahoot!, Minecraft, and Genially have been successfully implemented to enhance student interest in mathematical problem-solving (Huang et al., 2020). Gamification strategies leverage mechanics such as competition, rewards, and progress tracking to maintain student interest and ensure content retention. Research has shown that gamified learning environments improve student participation, foster intrinsic motivation, and promote deeper conceptual understanding (Sailer & Homner, 2020).

In this paper we present the implementation of a virtual EER titled "Pi Museum", designed to promote interactive mathematics learning in the 6th grade, within the celebration of the International Day of Mathematics.

The aim of this study is to understand how students perceived the created activity.

Escape Rooms and Learning

Escape rooms (ERs) are a relatively recent form of entertainment designed to provide an unforgettable experience. According to Scott Nicholson, they can be defined as "live-action team-based games where players accomplish tasks while participating in multiple procedures, in one or more spaces, with a specific goal, in a limited period of time" (Nicholson, 2015, p.1). ERs first emerged in Japan in 2007 but have since gained worldwide popularity, with rooms now available across most continents, including Asia, Europe, and America (Makri, Vlachopoulos and Martina, 2021).

ERs offer players an immersive narrative experience, constructing a meaningful and memorable escape scenario. These narratives establish the game's atmosphere and serve as the foundation for the player's emotional engagement and curiosity (Clarke et al., 2017). Participants are transported into a narrative framework where they encounter intriguing challenges and missions. Whether assisting Alice in escaping from Wonderland or capturing a group of thieves who have stolen valuable artwork from a museum, or retrieving essential notes from a locked school locker before an upcoming exam, or discovering the formula to cure a global pandemic, these narrative-driven scenarios elicit emotional engagement and curiosity among players. A sense of urgency and risk is typically sustained throughout the experience by incorporating time manage-

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

ment techniques, actors, props, and external influences, encouraging players to engage fully and strive to complete the challenge on time (Clarke et al., 2017).

"Although escape rooms are adventure activities, while playing, players must use multiple analytical skills, thinking skills, problem-solving, cooperation, and communication skills, which takes the whole activity to a higher cognitive level" (Huraj, Hrmo and Sejutová Hudáková, 2022, p.2). As they progress through the rooms and solve the presented challenges, the game atmosphere is established, fostering engagement and a sense of adventure.

Educational Escape Rooms

ERs have become a popular recreational activity, which has also attracted the interest of teachers and educators in recent years. Educators are increasingly motivated to integrate ER games into diverse educational contexts. They have been inspired to adapt ER games across various fields of education (Clarke et al., 2017; Nicholson, 2018) as a means of fostering playful and productive failure techniques that encourage continuous development (Whitton, 2018).

EERs have been shown to be an engaging and enjoyable activity when introduced into the classroom. At the same time, they have proven to be a valuable tool through which, while attempting to escape the room, students can develop both soft skills and subject-specific competencies (Morrell et al., 2020; Sowell, 2020). A systematic review conducted by Fotaris and Mastoras (2019) highlights their positive impact on student motivation and the development of soft skills, including teamwork, creativity, decision-making, leadership, communication, and critical thinking. Additionally, it emphasises the enjoyable and immersive nature of the experience, which positions students as active participants in the learning process.

"The Escape Rooms methodology provides a playful foundation for learning experiences to be designed in a more contextualised manner. Using narratives […] could invoke the much-needed curiosity and motivation to be persistent in problem-solving" (Arnab et al., 2021, p.2).

Digital Educational Escape Rooms

Digital EERs are essentially the online counterpart of traditional ERs, which were initially designed for entertainment or adapted for classroom learning activities. However, this transition is not merely a straightforward conversion; it necessitates the integration of key game elements, including structure, background narrative, and puzzle design. As emphasised by Veldkamp et al. (2020), these components must be carefully aligned with the intended educational objectives.

The expansion of digital platforms has facilitated the emergence of digital ERs. These digital versions enable students to experience the excitement of searching for clues and the satisfaction of solving puzzles on their digital devices, whether at home, on mobile devices, or school computers. According to Huang et al. (2020), digital ERs can be regarded as "an innovative teaching method that combines digital content with real-world elements."

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

Digital ERs, also referred to as digital breakouts, offer an effective approach to incorporating play and problem-solving into a lesson. They can serve as an engaging activity for the entire class or as an alternative for students who progress more rapidly than their peers (Ang et al., 2020).

When creating a Digital Educational Escape Room (DEER) with a learning focus, four key aspects should be taken into account:

1. **Learning Objectives** – Clearly define the goals to ensure the content is effectively addressed, assess students' learning outcomes, and identify areas that require improvement.
2. **Single or Multidisciplinary Theme** – Determine whether the game will concentrate on a specific subject or incorporate multiple disciplines to enrich the learning experience.
3. **Soft Skills Development** – Integrate interactive elements that foster essential soft skills such as communication and teamwork.
4. **Problem-Solving** – Include challenges that encourage critical thinking and maintain player engagement, ensuring an enjoyable and stimulating experience (Lior, 2020, p. 25).

Reuter et al. (2021) emphasised that many educators are often unaware of effective strategies for designing DEERs. A key challenge in practice is that many teachers have limited familiarity with game design principles and rarely apply recommended models, frameworks, and evaluation tools when developing digital or hybrid escape games for their classrooms. Hakshurian (2023) argues that teacher training programmes are essential, as not all educators possess the necessary skills and knowledge to design effective escape games.

To address this, various online platforms have been developed to assist in creating game environments, locks, and puzzles, including Google Slides, Genially, Thinglink, Google Sites, Canva, Google Forms, LearningApps, Flippity, and Padlet (Ambrožová & Kaliba, 2021; Repetto et al., 2023; Şahin, 2023). Recent research (Cooper, 2023; Hadi Mogavi et al., 2024; Pérez Colado et al., 2023) has also highlighted the significant role artificial intelligence can play in facilitating the development of digital escape rooms.

There is growing empirical evidence to suggest that the use of digital escape rooms in education can have a positive impact on student engagement and learning outcomes. Numerous studies have shown that digital escape rooms can enhance student engagement and motivation (Yllana-Prieto et al., 2023; Huraj et al., 2022; Pais et al. 2024).

In this context, the present work describes the development and implementation of the "Pi Museum," an EER focused on Mathematics, applied in a school setting to reinforce essential mathematical concepts and foster student motivation.

Methodology

The case study (Yin, 1994) was the research method used to assess the potential of the activity.

The EER was implemented in three 6th-grade classes at Escola Básica de Gouveia in Portugal, as a formative assessment tool. A total of 75 students participated in the activity, working

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

in groups of three to complete the ER challenges. The participants exhibited varying levels of mathematical proficiency, and the groups were formed to ensure balance in this regard.

Inquiry techniques, direct observation, and document analysis were used, employing the following instruments: field notes, questionnaires, and written productions by students. During the task implementation, the teacher (first author of this article) adopted the participant observation technique. The written productions were handed in to the teacher. Students were asked to fill in two questionnaires, one in groups and another individually. The first questionnaire allows them to reflect on aspects related to the Escape Room, the groups' performance and the way the activity went, as well as giving them the chance to make suggestions. The purpose of the second questionnaire was to analyse the results of an individual evaluation of the "Pi Museum" activity, using a form that exists in the school for the activities in the Annual Activities Plan. The questionnaires included lists of statements and respondents were asked to rate their level of agreement using a 5-point agreement (Likert) scale. The statements were about the ER activity, such as contribution for learning, the difficulties experienced, and the entertainment component of the activity. Statistical analysis of the data, specifically descriptive statistics, was performed using Excel.

The Educational Escape Room "Pi Museum"

Genially is a platform that allows users to create interactive content and experiences without needing to code. It offers several features including gamification tools and within these, it provides a large set of ER templates.

The "Pi Museum" was developed using Genially and consists of four virtual rooms, each containing five mathematical challenges related to Pi. The puzzles took the form of multiple-choice questions, most with 3 options and a few with two options. Students' progress through the rooms by solving these problems correctly within a set time frame. Each room was designed to progressively increase in difficulty, ensuring a balance between challenge and skill development. "Pi Museum" starts with the opening image shown in Figure 1 (top-left) and can be accessed in https://view.genially.com/63c1887482c67f001892be0e/interactive-content-escape-roommuseu-do-pi.

In the first three rooms, students recover a stolen painting for each correct answer. Each room contains five missing paintings that must be recovered before progressing to the next room. Figure 1 illustrates the first room as students enter (top-right) and the third room after completion (bottom-left).

The final room follows a different format. There, students must complete a puzzle featuring the first digits of Pi arranged along a spiral. Figure 1 (bottom-right) depicts the final room during an intermediate challenge.

Throughout the ER, if a group answers a challenge incorrectly, an image appears, indicating a failed attempt. When this happens, the group is redirected back to the question/problem slide to try again.

Each time a team answers correctly, a counter in the upper left corner of the slide updates to reflect their progress (Figure 1, top-right). The disadvantage of Genially, in its free version, is

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

that it doesn't provide a student performance report at the end. Thus, it was necessary to resort to an activity script, in paper version, to monitor the groups' performance. Each group had to write down the justification (calculations) for each challenge and note how many attempts were needed.

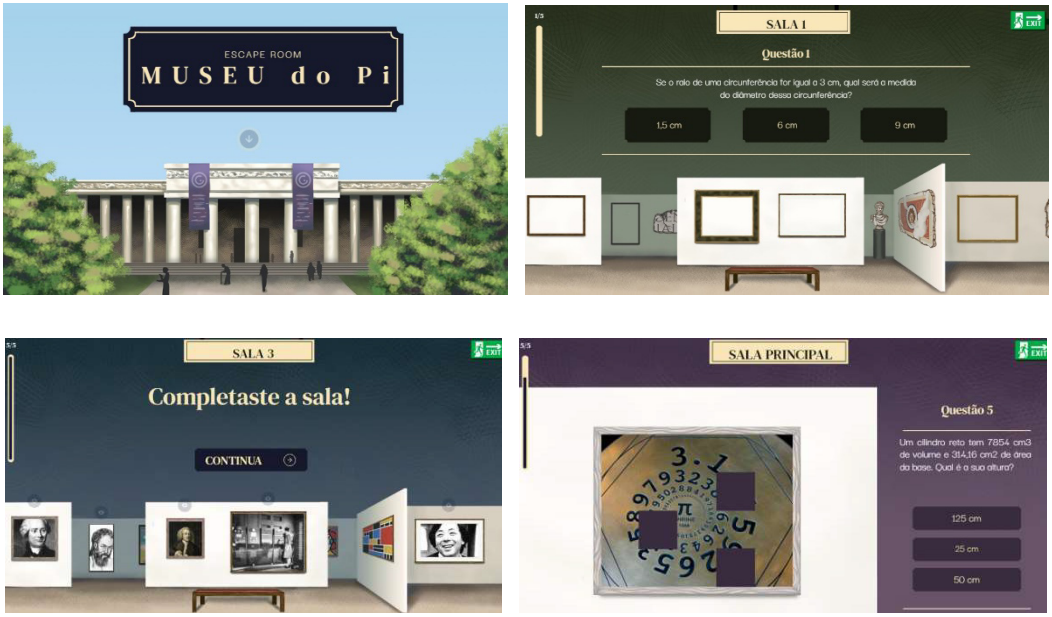

Figure 1. Pi Museum, opening slide (top-left), entering first room (top-right), completed third room (bottom-left) and final room (bottom right)

After completing all challenges in a room, a slide appears displaying the total number of recovered paintings, each marked with an "eye" symbol. When students hover over this eye with the computer mouse, a pop-up appears on the screen providing historical information about Pi, enriching their understanding of this mathematical constant.

The challenges were designed to be interactive and stimulate students' logical thinking. Pi is the first irrational number encountered by students in their formal education, and irrational numbers inherently add complexity to mathematical understanding. By familiarizing students with Pi, their progression through mathematics is facilitated.

The "Pi Museum" ER was applied on March 14th and 15th, 2023, celebrating the International Day of Mathematics. The implementation followed a structured process:

1. Introduction and Instructions: Students were introduced to the activity and provided with an overview of how to navigate the Genially platform.
2. Game Execution: Students engaged in solving challenges within the ER, collaborating with their peers to progress through each level.
3. Feedback and Reflection: After completing the ER, students received immediate feedback on their responses, allowing for meaningful learning reinforcement.

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

4. Questionnaire and Discussion: Students completed a questionnaire to assess their perceptions of the activity, followed by a class discussion on their experiences.

The game objectives were:

- Reinforcement of students' knowledge of the number Pi, its history, and applications.
- Reinforcement of knowledge of perimeters, areas, and volumes, involving the number Pi whenever possible.
- Development of logical reasoning and the ability to solve mathematical problems.
- Stimulation of collaborative work and autonomy in learning.
- Introduction to gamification as a didactic tool to engage students in the learning process.

Figure 2 contains some photographs that express the students' engagement to the activity during the "International Mathematics Day" celebration.

Figure 2. Students engaging in the "Pi Museum" activity

Results and Discussion

The analysis of the results was based on the observation of students' performance and on feedback gathered throughout the experience, including the paper scripts filled in during the activity. Two questionnaires (the 1st in group and the 2nd individually) were applied to students to assess their perception of the activity and its impact on learning.

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

During the game's application, a high level of interaction and collaboration was observed among the students, who actively engaged in discussing strategies and solutions for solving the challenges. The interactive nature of the EER facilitated peer learning, with students often explaining concepts to one another.

Analysis of student responses to the challenges and their justification in the paper script indicated, in general, a high success rate, demonstrating a strong understanding of the concepts covered.

Table 1 summarizes the number of questions each group answered correctly on the 1st attempt or the 2nd/3rd attempts. Analyzing the results, we find that the only group that answered all questions correctly on the 1st attempt was 6B, and the group that missed the most answers on the 1st attempt was 4B, standing out from all other groups. Group 4B did not pay due attention to the necessary guidelines for completing the task and started answering by trial and error until they got it right. Only later did they restart the ER to record the respective justification in the paper script handed over by the teacher. From the outset, all the other groups recorded their justification in the script provided for the purpose. From an analysis of the students' output, we can see that they presented adequate solutions, having corrected their reasoning from the first to the second attempt.

Overall, all groups engaged in the ER's development, were motivated, worked well in groups, shared knowledge, consolidated learning, and became familiar with a new digital resource.

In the first questionnaire students were asked to rate in a 5 point Likert scale (1 - lowest score; 5 - highest score; 0 – no answer) several aspects of the ER. In all questions the answers could be complemented with comments or justifications. All 19 groups answered the questionnaire.

First, they were asked about which aspects they enjoyed the most. Figure 3 shows the results.

Analyzing the graph in Figure 3, we observe that the various groups enjoyed the "Pi Museum" ER. There was a high level of consensus across the different aspects evaluated, with the majority of groups selecting the highest scores (4 or 5) for all options. The average score for each category ranged between 4.11 and 4.63.

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

Table 1. Summary of attempts by group

	Correct answers	
Group	**1st attempt**	**2nd/3rd attempts**
1A	16	4
2A	16	4
3A	14	6
4A	17	3
5A	17	3
6A	19	1
7A	19	1
1B	15	5
2B	16	4
3B	14	6
4B	6	14
5B	19	1
6B	20	0
1C	13	7
2C	16	4
3C	12	8
4C	14	6
5C	18	2
6C	15	5

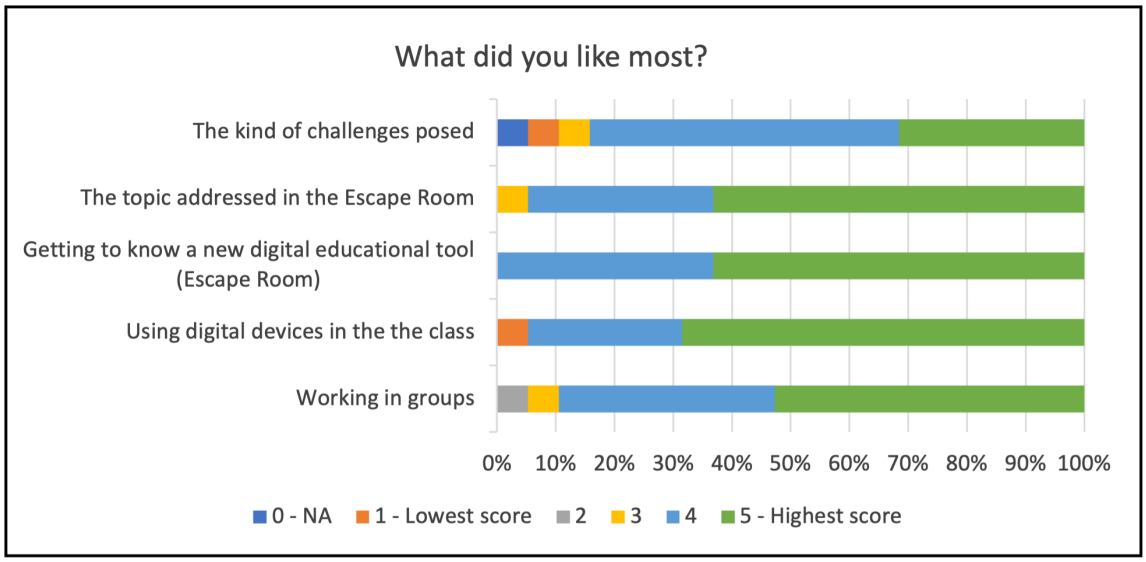

Figure 3. Bar chart of responses to the question “What did you like most?”

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291
ISSN: 1647-3582

The statement “Getting to know a new digital educational tool (Escape Room)” received the highest rating, with no evaluations below 4. However, one group assigned the lowest score to the options “Using digital devices in the classroom” and “The kind of challenges posed”. The latter received the lowest number of maximum scores and had the lowest average rating (4.11).

The option “Working in groups” generated mixed opinions, as two groups reported that team dynamics did not function effectively, resulting in scores of 2 or 3.

Secondly, they were asked about where they found the most difficulties. Figure 4 shows the results.

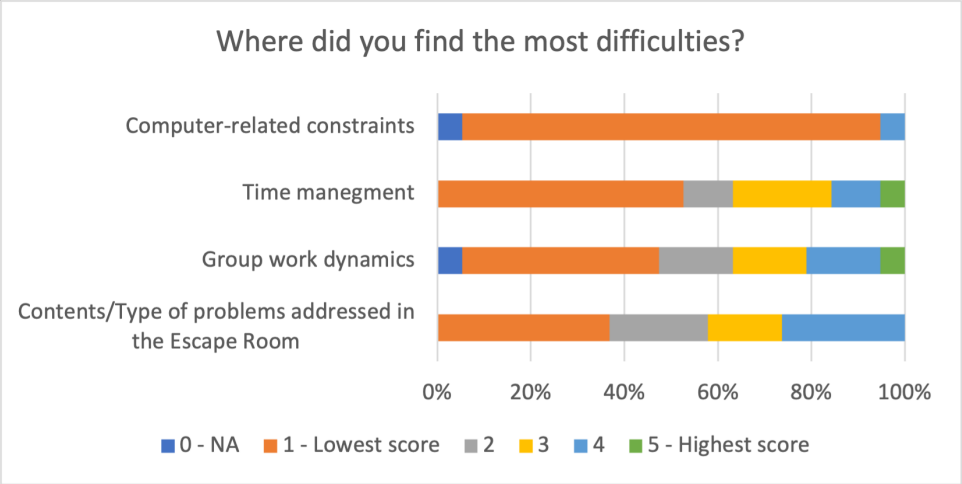

Figure 4. Bar chart of responses to the question “Where did you find the most difficulties?”

As observed in the analysis of Figure 4, overall, the groups did not experience significant difficulties, as more than 50% selected the lowest score options.

Among the groups that assigned higher scores (3, 4, and 5) to specific challenges, 42% selected “Content/type of problems addressed in the Escape Room”, while 37% selected “Group work dynamics” and “Time management”, respectively.

Only one group assigned a high score to “Computer-related constraints”, justifying their choice with “Problems with the keyboard.”

Additionally, the group that gave the maximum score to “Group work dynamics” explained their decision by noting that “The group was not well organized.”

Students were also asked about which rooms they liked most. Figure 5 shows the results.

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

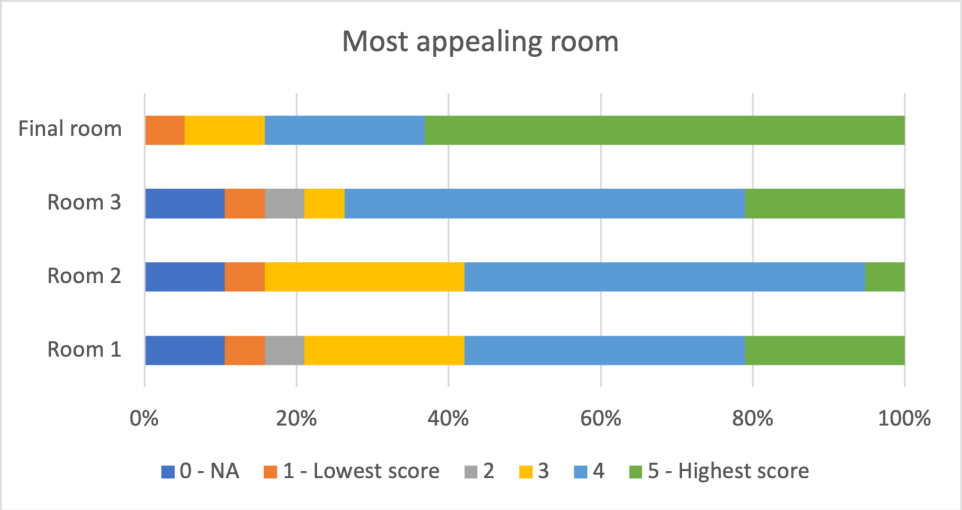

Figure 5. Bar chart of responses to the question “Which rooms did you like the most?”

The final room, which required more complex problem-solving, was the most challenging but also the most engaging, receiving 63% of responses with the highest score.

Conversely, the least engaging rooms, according to most groups, were Rooms 1 and 2.

Students justified their selection of the most appealing rooms with statements such as:

- “Room 1, because the following ones increased in difficulty.”
- “Final Room, because we got everything right.”
- “Final Room, because we discovered a puzzle and saw the infinite number π.”
- “Final Room, because we liked the exercises and the background image.”
- “Final Room, because it had more interesting problems that required deeper reasoning.”

When asked about their overall performance, the majority answered positively, as can be seen in Figure 6.

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

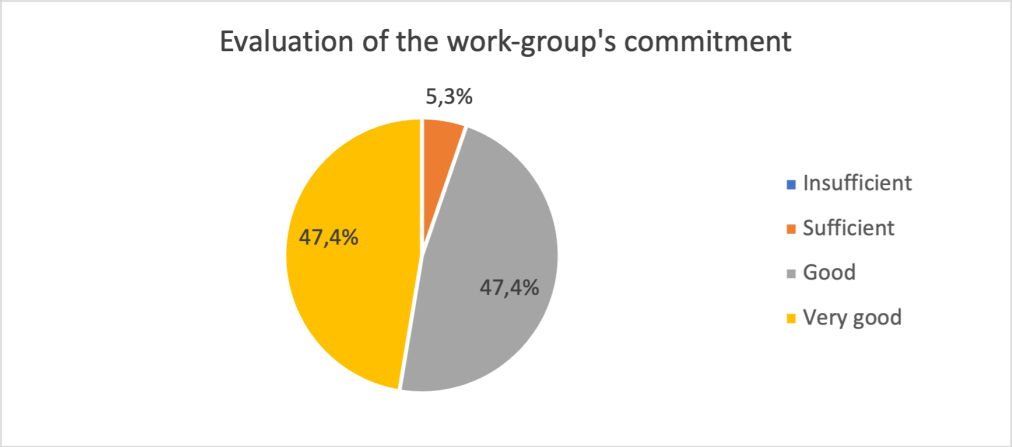

Figure 6. Pie chart of responses to the self-evaluation of the group performance.

The groups rated their effort in the ER as either “Good” or “Very Good”, with an equal number of responses (9). Only one group rated their performance as “Sufficient”, justifying their score by stating that their team was highly heterogeneous. In this group, most of the work was carried out by a single member, as the others faced significant difficulties in the subject. Despite dividing the tasks, some members did not complete them as expected.

Groups that rated themselves as “Good” provided justifications such as:

- “We couldn’t get everything right as we wanted.”
- “We were always arguing.”
- “We answered almost all the questions on the first attempt and worked together.”
- “We worked very well as a group, but we couldn’t get some questions right on the first attempt.”
- “We worked together, finished in a good time, made only a few mistakes, and listened to each other.”

Groups that rated themselves as “Very Good” provided justifications such as:

- “We worked together and very well.”
- “We stayed united.”
- “Even with one less team member, we managed to get almost everything right in approximately 45 minutes.”
- “We solved the problems with practically no difficulty.”
- “Everyone contributed to finishing and correctly solving the questions.”

The last question was an open question and asked the groups if they would like to repeat this type of activity, and why? All groups stated that they would like to repeat the experience.

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291
ISSN: 1647-3582

As it was an open question, the justification varied considerably but focused on one or more of the following aspects: it allowed them to work in groups, use digital tools, gain more knowledge about the history of π, solve more problems, develop reasoning, review subjects, create different dynamics, and increase their liking for Mathematics. Several groups highlighted that it was an interesting, exciting, and fun activity. One group provided a particularly comprehensive answer: 'Yes, because we learned more, we learned to work as a team, to respect the opinions of our colleagues. It was very educational and fun.'

After evaluating the activity in groups, each student was asked to complete an individual questionnaire. The sample consisted of 57 students. The scale used in this evaluation was also from 0 to 5, where 0 meant no answer 1 the lowest score, and 5 the highest score. Figure 7 summarizes the results.

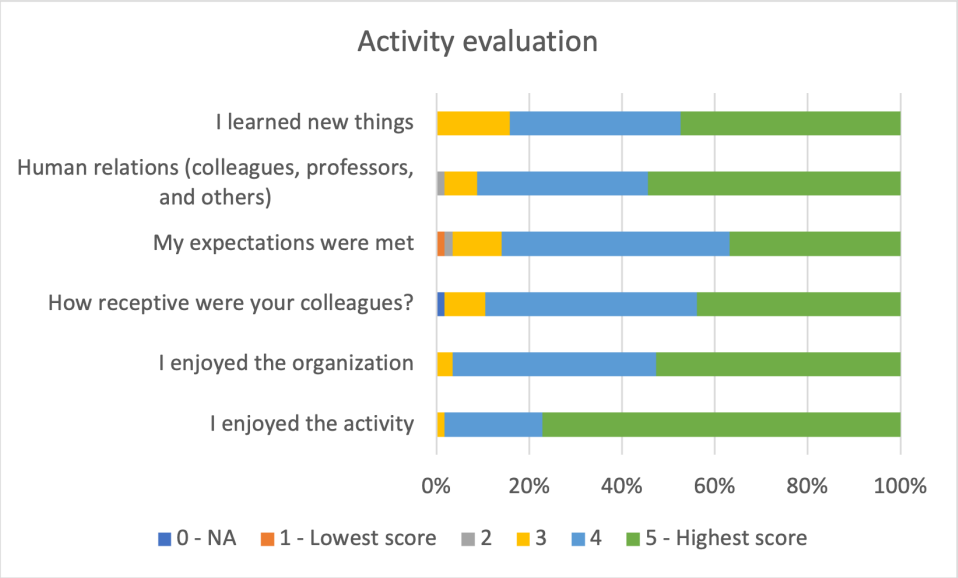

Figure 7. Bar chart of responses to the individual self-evaluating questions.

All parameters were rated with the highest scores by most students. The average score for the various parameters ranged approximately between 4.18 and 4.75.

Only the parameters "Human relations" and "My expectations were met" received the lowest scores (1 or 2) from one and two students, respectively.

The questionnaire allowed students to provide suggestions, with the most frequently mentioned being: "We should do this activity more often, with different topics." Other student proposals included:

- The activity should be a bit longer.
- The ER could have more rooms.
- An ER with slightly easier problems.

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

Conclusions

In this paper we analysed the implementation of a virtual EER, “Pi Museum”, designed using the platform Genially. It was created to promote interactive mathematics learning in the 6th grade, within the celebration of the International Day of Mathematics.

Students worked in groups to solve the challenges presented in the ER, which was based on the Geometry and Measurement content covered at this educational level, incorporating the mathematical constant π as much as possible.

Today, it is well known that gamification enhances the learning process, making it more engaging and interactive. However, it should be incorporated in a way that integrates curricular content, providing an educational experience that balances challenge and fun. According to recent studies, technology-assisted gamification activities improve the learning curve (Kayımbaşıoğlu, Oktekin, & Haci, 2016). This aligns with the primary goal of any teacher: to ensure that all students learn more effectively.

Following the implementation of the ER in the three classes, it was confirmed that integrating this innovative and interactive methodology into the teaching practice was highly appreciated by students. Their engagement and commitment were evident throughout the resolution of the challenges. Moreover, students who faced greater difficulties benefited from teamwork, improving their understanding of the concepts covered.

The dynamic and immediate feedback provided by the game allowed students to review their performance, reflect on their responses, and work collaboratively to overcome challenges and find the correct answers. This process fostered autonomous learning, which is essential for developing active and responsible citizenship in the future.

The implementation of the “Pi Museum” EER demonstrated that gamification can be an effective strategy for enhancing mathematics education. The findings suggest that the EER was both an educational and enjoyable activity. The key benefits identified by participants included:

- The opportunity to work in teams, allowing them to collaborate and learn from their peers.
- The use of interactive digital tools, which facilitated the comprehension of mathematical concepts.
- The development of logical reasoning through playful problem-solving, making learning more engaging and accessible.
- The experience provided by the ER’s engaging storyline, which enhanced motivation and involvement.

Students emphasized the innovative and dynamic nature of the activity, mentioning that the experience was more stimulating than a conventional lesson. The interactive format, combined with the problem-solving aspect, helped maintain high levels of interest and motivation throughout the activity.

Among the different rooms, the Final Room was the most appreciated by students, as it contained interactive challenges that required active collaboration among participants. Through direct observation, it could be seen that the complexity of this stage encouraged deeper engagement, reinforcing teamwork and critical thinking.

Indagatio Didactica, vol. 17 (1), junho 2025 ISSN: 1647-3582
https://doi.org/10.34624/id.v17i1.40291

Despite the overwhelmingly positive feedback, students also highlighted some challenges they faced during the activity. These included the difficulty of certain problems, which some found particularly complex, and the suggestion to extend the duration of the game, allowing for a more thorough exploration of the challenges presented.

Overall, the results suggest that gamification through digital ERs is an effective pedagogical tool that not only reinforces mathematical knowledge but also enhances teamwork, problem-solving skills, and student engagement in learning activities. We can conclude that using gamification as a learning tool is a valuable asset for education. It is a resource teachers can use to motivate students, reinforce content, or review topics. For sure, the activity was well received by all students.

Future research should explore the long-term impact of EERs on student learning outcomes and investigate their applicability in other mathematical domains. The integration of adaptive learning mechanisms and real-time feedback could further enhance the educational value of EERs. Additionally, comparative studies between traditional and gamified learning approaches could provide further insights into the effectiveness of ER methodologies in education.

Authors contributions

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

Funding

This work is supported by CIDMA under the FCT (Portuguese Foundation for Science and Technology) Multi-Annual Financing Program for R&D Units, within project reference UID/04106.

References

Ambrožová, P., & Kaliba, M. (2021). Online escape games as an educational tool. In L. Gomez Chova, A. Lopez, & I. CandelTorres (Eds.), *ICERI2021 Proceedings* (pp. 5998-6003). IATED Digital Library. https://doi.org/10.21125/iceri.2021.1353

Ang, J. W. J., Ng, Y. N. A. & Liew, R. S. (2020). Physical and digital educational escape room for teaching chemical bonding. *Journal of Chemical Education*, *97*, 2849-2856. https://doi.org/10.1021/acs.jchemed.0c00612

Arnab, S., Eyre, E., Noon, M., Kernaghan-Andrews, S. & Mahon, D. (2021). An Adaptation of the 'Escape Rooms' Methodology in Online Learning to Facilitate and Investigate Active Learner-led Activities

Indagatio Didactica, vol. 17 (1), junho 2025 ISSN: 1647-3582
https://doi.org/10.34624/id.v17i1.40291

and Experiences. In: P. Fotaris (Ed.), *Proceedings of the 15th European Conference on Game Based Learning, ECGBL 2021*, (pp. 1-13). Academic Conferences and Publishing International Limited.

Attard, C. (2013) If I had to pick any subject, it wouldn't be maths: foundations for engagement with mathematics during the middle years. *Mathematics Education Research Journal 25*, 569–587. https://doi.org/10.1007/s13394-013-0081-8

Boaler, J. (2022). *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching,* 2nd Edition. Jossey-Bass.

Clarke, S. J., Peel, D. J., Arnab, S., Morini, L., Keegan, H., & Wood, O. (2017). EscapED: A Framework for Creating Educational Escape Rooms and Interactive Games to For Higher/Further Education. *International Journal of Serious Games*, *4*(3). https://doi.org/10.17083/ijsg.v4i3.180

Cooper, G. (2023). Examining science education in ChatGPT: An exploratory study of generative artificial intelligence. *Journal of Science Education and Technology*, *32*(3), 444-452. https://doi.org/10.1007/s10956-023-10039-y

Fotaris, P. & Mastoras, T. (2019). Escape Rooms for Learning: A Systematic Review. In L. Elbaek, G. Majgaard, A. Valente and S. Khalid (eds.) *Proceedings of the 13th European Conference on Game Based Learning, ECGBL 2019*. (pp. 235-243). Academic Conferences and Publishing International Limited.

Gutiérrez-Fallas, L. (2024). Escape Room no ensino das funções: uma experiência de gamificação. *Debates em Educação*, 16(38), e16081. https://doi.org/10.28998/2175-6600.2024v16n38pe16081.

Hadi Mogavi, R., Deng, C., Juho Kim, J., Zhou, P., Kwon, Y. D., Hosny Saleh Metwally, A., Tlili, A., Bassanelli, S., Bucchiarone,A., Gujar, S., Nacke, L. E., & Hui, P. (2024). ChatGPT in education: A blessing or a curse? A qualitative study exploring early adopters' utilization and perceptions. *Computers in Human Behavior: Artificial Humans*, *2*(1), Article 100027. https://doi.org/10.1016/j.chbah.2023.100027

Hall, A., Pais, S., Morando, P. & Spreafico, M. (2024). Fun and Functional: Using Non-Digital Games to Promote Maths Engagement in Pre-service Teachers. *Proceedings of the 18th European Conference on Game Based Learning, ECGBL 2024*, *18*(1), 337-346 https://doi.org/10.34190/ecgbl.18.1.2675

Hakshurian, Y. (2023). Teachers' competencies in developing digital educational escape rooms. *Educatia 21 Journal*, *25,* Article 7. https://doi.org/10.24193/ed21.2023.25.07

Huang, S.-Y., Kuo, Y.-H. & Chen, H.-C. (2020). Applying digital escape rooms infused with science teaching in elementary school: Learning performance, learning motivation, and problem-solving ability. *Thinking Skills and Creativity*, (37), 100681. https://doi.org/10.1016/j.tsc.2020.100681

Huraj, L.; Hrmo, R. & Sejutová Hudáková, M. (2022). The Impact of a Digital Escape Room focused on HTML and Computer Networks on Vocational High School Students. *Educational Sci*ences, *12*(10), 682. https://doi.org/10.3390/educsci12100682

Kayımbaşıoğlu, D., Oktekin, B., & Haci, H. (2016). Integration of gamification technology in education. *Procedia Computer Science 102,* 668-676. https://doi.org/10.1016/j.procs.2016.09.460

Lior, S. (2020). Studying big data using virtual escape rooms. *International Journal of Advanced Statistics and IT&C for Economics and Life Sciences*, 10(1), 23–30. https://doi.org/10.2478/ijasitels-2020-0004

Makri, A., Vlachopoulos, D. & Martina, R. (2021). Digital Escape Rooms as Innovative Pedagogical Tools in Education: A SystematicLiterature Review. *Sustainability*, *13*(8)*,* 4587*;* https://doi.org/10.3390/su13084587

Morando, P. & Turconi, P. (2022). Brains on in math classes. *EDULEARN22 Proceedings,* 1522–1529. https://doi.org/10.21125/edulearn.2022.0401

Morrell, B., Eukel, H. & Santurri, L. (2020). Soft skills and implications for future professional practice: Qualitative findings of a nursing education escape room, *Nurse Education Today*, *93*, 104462. https://doi.org/10.1016/j.nedt.2020.104462

Indagatio Didactica, vol. 17 (1), junho 2025
https://doi.org/10.34624/id.v17i1.40291

ISSN: 1647-3582

National Council of Teachers of Mathematics. (2020). *Catalyzing Change in Early Childhood and Elementary Mathematics: Initiating Critical Conversations.* National Council of Teachers of Mathematics.

National Research Council. (2002). *Helping Children Learn Mathematics*. The National Academies Press. https://doi.org/10.17226/10434.

Nicholson, S. (2018). Creating Engaging Escape Rooms for the Classroom. *Childhood Education*, *94*(1), 44-49. https://doi.org/10.1080/00094056.2018.1420363

Nicholson, S., 2015. Peeking behind the locked door: A survey of escape room facilities. http://scottnicholson.com/pubs/erfacwhite.pdf

Pais, S., Sousa, A. & Lopes, M. (2024). Play2escape - A Digital Escape Room In Math Classes For Undergraduate Tourism Students - Case Study. Proceedings of *18th Multi Conference on Computer Science and Information Systems*, 59-66. http://hdl.handle.net/10773/43434

Pérez Colado, I. J., Pérez Colado, V. M., Calvo Morata, A., Santa Cruz Píriz, R., & Fernández Manjón, B. (2023). Using newAI-driven techniques to ease serious games authoring. In T. Hammond & H. Hogan (Chairs), *Proceedings of the 2023IEEE Frontiers in Education Conference* (pp. 1-9). IEEE. https://doi.org/10.1109/FIE58773.2023.10343021

Repetto, M., Bruschi, B., & Talarico, M. (2023). Key issues and pedagogical implications in the design of digital educational escape rooms. *Journal of E-Learning and Knowledge Society*, *19*(1), 67-74. https://doi.org/10.20368/1971-8829/1135749

Reuter, J., Ferreira Dias, M., Amorim, M., Figueiredo, C., & Veloso, C. (2021). How to create educational escape rooms? Strategies for creation and design. In F. J. García-Peñalvo and A. García-Holgado, (Eds.), *TEEM'20 Proceeding: Eighth International Conference on Technological Ecosystems for Enhancing Multiculturality* (pp. 694-698). Association for Computing Machinery. https://doi.org/10.1145/3434780.3436664

Şahin, G. (2023). Designing a digital escape room game: An experience of a digital learning tool in basic education. *Journal of Educational Technology & Online Learning*, *6*(4), 925-946. http://doi.org/10.31681/jetol.1334912

Sailer, M. & Homner, L. (2020). The Gamification of Learning: a Meta-analysis. *Educational Psychology Review, 32*, 77–112. https://doi.org/10.1007/s10648-019-09498-w

Santos, V., Pais, S. & Hall, A. (2021). Mathematics Classes for Tourism Undergraduate Students and Pre-service Teachers with Active Methodologies using Technologies, *International Journal of Technology in Mathematics Education*, *28*(3), 203-212. https://doi.org/10.1564/tme_v28.3.10

Whitton N. (2018). Playful learning: tools, techniques, and tactics. *Research in Learning Technology*, *26*. https://doi.org/10.25304/rlt.v26.2035

Yin, R. (1994). *Case study research: design and methods*. Thousand Oaks: Sage Publications.

Yllana-Prieto, F.; González-Gómez, D. & Jeong, J.S. (2023). Influence of two educational Escape Room–Breakout tools in PSTs' affective and cognitive domain in STEM (science and mathematics) courses. *Heliyon, 9*, e12795. https://doi.org/10.1016/j.heliyon.2023.e12795