

Scientific Escape Room: A Science Communication Initiative Evaluated by Generic Learning Outcomes

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Abstract: The Scientific Escape Room, located at the Science Center of the Federal University of Juiz de Fora (UFJF), is a university extension project that emerged as a science communication initiative to engage people with science in a fun, interactive, and collaborative way. The narrative, titled *The Last Experiment*, proposes that participants, supposedly kidnapped to serve as experimental subjects, solve a series of puzzles to escape the room. The space was designed to simulate the clandestine laboratory of a fictional pharmaceutical company, enhancing the game's immersive nature. The challenges were based on knowledge related to the natural sciences (chemistry, physics, and biology) and mathematics, aligned with school-level content and varying in complexity. The target audience comprised individuals aged 18 and over who had completed basic education, which in Brazil spans ages 4 to 17. The puzzles involve revealing clues with ultraviolet light, interpreting information from the periodic table, solving encrypted messages, interpreting health-related information such as body mass index (BMI), applying concepts related to magnetism and the properties of metals, and, finally, using logical reasoning and pattern recognition. Since game-based learning addresses not only cognitive but also social and emotional aspects, the game was analysed within the theoretical framework of Generic Learning Outcomes (GLOs), which offers a broader perspective on learning. The study adopted a qualitative approach based on content analysis of post-game questionnaires and semi-structured interviews with returning players. The results demonstrate that players' experiences encompassed the five dimensions of the GLOs—knowledge and understanding; skills; values and attitudes; enjoyment, inspiration, and creativity; and action, behaviour, and progression (Hooper-Greenhill, 2007)—highlighting improvements in cognitive, social, and emotional development. Participants reported that the activity fostered teamwork and logical reasoning and, after the experience, expressed greater motivation to understand the scientific concepts involved in the puzzles and return to the escape room to solve them. The experience reinforces the potential of game-based learning to foster curiosity, collaboration, and the application of scientific knowledge.

Keywords: Escape room, Science communication, Generic learning outcomes, Game-based learning, University extension, Non-formal education

1. Introduction

The communication of scientific knowledge plays a fundamental role in bridging science and society by making knowledge that has historically remained restricted to academic circles accessible (Massarani & Moreira, 2021). This process contributes to the development of more critical citizens capable of interpreting information and making informed decisions about issues involving science and technology (Castelfranchi, 2010). In this context, it is important that science communication initiatives, especially those carried out in non-formal educational settings (Marandino, 2014), such as science centers, are designed to address not only cognitive but also social and emotional aspects. One way to achieve this is by drawing on the theoretical frameworks of playfulness (Luckesi, 2002) and Game-Based Learning (GBL) (Gee, 2003), as they encompass social interaction and affective dimensions.

In this context, collaborative games such as escape rooms have gained prominence. They can be defined as interactive activities in which participants enter a room and leave only after solving a series of puzzles (Borrego et al., 2017). Unlike other collaborative game-based learning approaches, such as educational role-playing games (RPGs) and board games, escape rooms are characterised by narratives integrated into physical environments, time constraints, and interconnected challenges. In science communication, escape rooms are an effective strategy for engaging diverse audiences—including families, friends, students, and educators—by presenting scientific concepts through an accessible, interactive, and immersive experience (Chiarello et al., 2025).

Many science communicators rely on traditional assessment methods typical of formal educational settings to evaluate playful science communication activities. However, in non-formal settings, assessment should seek to capture both the cognitive and affective dimensions experienced by participants. The Generic Learning Outcomes (GLO) framework is particularly appropriate because it encompasses not only cognitive and practical skills but also opinions and aspects related to social interaction, character, and emotions. More specifically, the framework distinguishes learning outcomes into five dimensions: (i) *knowledge and understanding*; (ii) *skills*; (iii) *attitudes and values*; (iv) *enjoyment, inspiration, and creativity*; and (v) *action, behaviour, and progression* (Hooper-Greenhill, 2007). Therefore, this study seeks to contribute to the growing body of research on the pedagogical value of escape rooms in science communication while also advancing the discussion on more appropriate models for evaluating such initiatives.

2. Methodology

This study adopts a qualitative approach, in which the researcher seeks to understand reality in a complex and contextualised manner based on the meanings attributed by the participants (Lüdke & André, 1986). Furthermore, the study is applied in nature, as it aims to produce knowledge for practical applications focused on specific issues (Triviños, 1987) related to the development, implementation, and evaluation of a Scientific Escape Room designed for science communication.

The research was developed through the planning and structuring of a Scientific Escape Room within the extension project entitled 'Science Communication Strategy Based on Recreational Science and Game-Based Learning: Implementation of a Scientific Escape Room at the UFJF Science Center'. The Science Center is a facility at the Federal University of Juiz de Fora (UFJF) dedicated to promoting science communication through interactive exhibitions, thematic workshops, public events, guided tours, and other activities. Beyond its role in science communication, it is also important to understand the planning, development, and evaluation processes involved in promoting the scientific culture of the target audience (Lordêlo & Porto, 2012).

The target audience comprised individuals over 18 years of age who had completed basic education, which in Brazil covers ages 4 to 17. Consequently, the participants were young people and adults aged over 18. The activity was offered free of charge, and interested participants registered in groups of three to six through the Eventbrite platform. The registration link was available on the UFJF Science Center website and on the Scientific Escape Room Instagram page (@escapeufjf).

Data were collected through an anonymous, voluntary post-game electronic questionnaire completed by participants and semi-structured interviews with some who returned to the room more than once. The questionnaire included both closed- and open-ended questions focusing on participants' perceptions of the experience, engagement, teamwork, motivation, and the level of challenge. The interviews further explored these topics, encouraging participants to elaborate on the scientific knowledge they used, their reasoning processes, group interactions, and the overall impact of the experience. Interviewees were selected through purposive sampling to capture the perspectives of participants who had experienced the activity more than once, thereby gaining a better understanding of how the activity is perceived in subsequent iterations.

The responses were analysed to identify which dimensions of the Generic Learning Outcomes (GLOs) framework (Hooper-Greenhill, 2007) were evidenced. For this purpose, Content Analysis (Bardin, 1977) was adopted, using the GLO dimensions as *a priori* categories. Based on this methodological approach, the next section presents the process of structuring the Scientific Escape Room.

3. Structuring the Scientific Escape Room

The conception of the activity began with the development of a narrative integrated into the construction of a themed setting, both grounded in the universe of science, from which the game's puzzles were structured. According to Salen and Zimmerman (2004), playing a game means interacting with and within a universe representing a space of possibilities with narrative dimensions. In this context, the narrative titled 'The Last Experiment' proposes that participants, supposedly kidnapped to serve as guinea pigs in a scientific experiment, solve a series of puzzles to escape the room. The setting was designed to simulate a clandestine laboratory of a fictional pharmaceutical company, enhancing the immersive feature of the game.



Figure 1: Images of the Scientific Escape Room. (Source: authors' archive)

Regarding the development of the puzzles that compound the game, they were based on knowledge related to the natural sciences (chemistry, physics, and biology) and mathematics, associated with school knowledge aligned with the Brazilian National Common Curricular Base, a document that regulates and guides the essential learning to which all Brazilian Basic Education students are entitled (Brazil, 2018). In this scenario, the challenges were created to have different levels of complexity, allowing the mobilization of elementary skills, such as investigating the environment and recalling scientific concepts, as well as more complex competencies related to the application and analysis of information (Anderson & Krathwohl, 2001). More specifically, the scientific concepts involved are related to the interaction of light with matter, reading and interpretation of the periodic table data, magnetism, properties of metals, specular reflection, and logical reasoning. Thus, the participants were expected to apply scientific knowledge and adopt typical scientific methodology procedures to solve the puzzles and progress in the game; that is, it was necessary to observe and explore the environment, create and test hypotheses—whether through the use of item combinations or password identification—and, finally, to draw conclusions (Sayde et al., 2022).

The organisation of the puzzles followed the hybrid approach (Nicholson, 2015), which allowed players to start in any order and then channel them into a single puzzle that unites everything and represents the final result. According to the author, this organisation allows group members to split up and solve different sequences of challenges at the same time. In this way, players could solve the easier puzzles at the beginning of the game and, as they gained confidence, tackle more complex puzzles.

Next, Figure 2 illustrates the path to finding the key that opens the room's door. The flowchart organises the challenges in a logical sequence for didactic purposes and to clarify the problem-solving path. In the game's dynamics, participants are not required to follow a pre-established order for solving the puzzles and can start with different ones according to their strategies and discoveries throughout the experience. However, in the end, it is necessary to solve all the puzzles to complete the challenge. The colours indicate the area of knowledge for each challenge, while the letters serve to identify them individually.

There's a brief presentation of the sequence of events corresponding to each line of reasoning below, which were organised so that each one leads to obtaining the code for a specific lock on the suitcase containing the key (blue lock and green lock, as indicated in Figure 2).

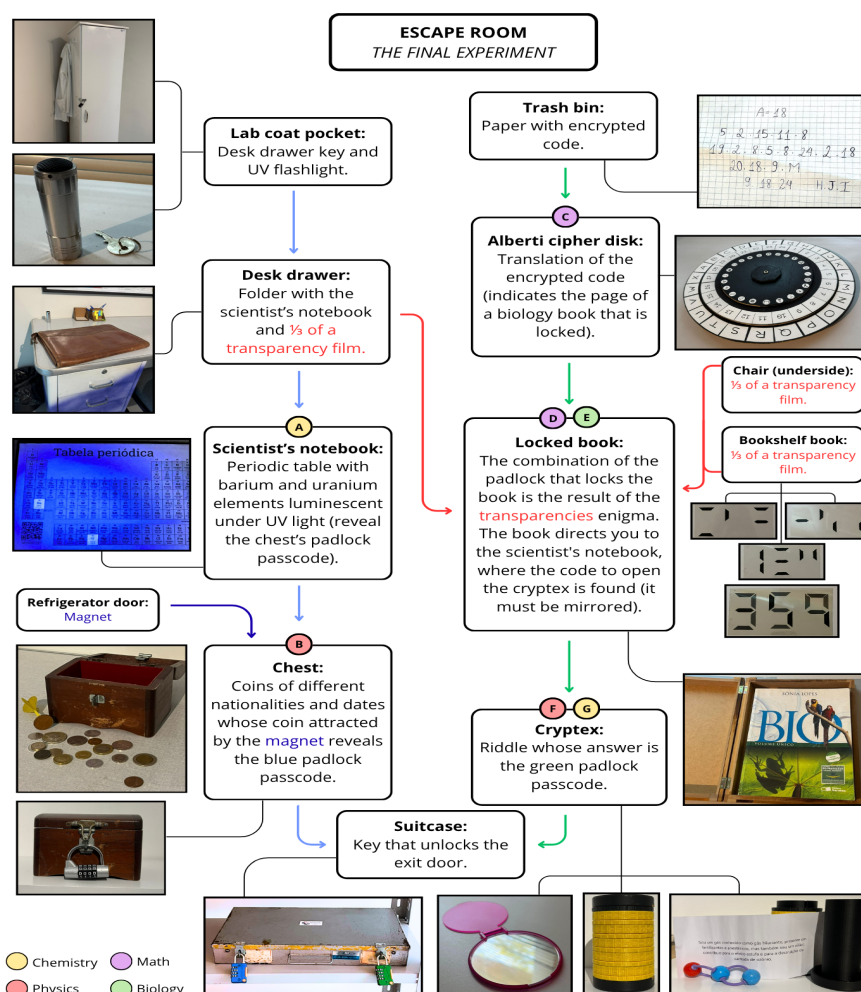


Figure 2: Flowchart of the Scientific Escape Room puzzles. Authors' source

3.1 Expected Path to Opening the Blue Lock

To solve the blue lock, the participants were expected to locate the key to a drawer and an ultraviolet (UV) flashlight. Opening the drawer revealed a notebook that contained, on its back cover, a periodic table in which the elements barium (Ba) and uranium (U) were highlighted under UV light. By identifying the highlighted elements, which form the word 'baú' (chest) in Portuguese, participants should use the respective atomic numbers to open a chest locked with a four-digit numeric lock (5692) (Puzzle A). Inside the chest were coins made of different metallic alloys, from various countries and values, of which only one allowed the correct code to be obtained. With the help of a magnet available in the room, participants were to identify the correct coin, the one which the minted date corresponded to the code for the blue lock (Puzzle B).

3.2 Expected Path to Opening the Green Lock

To solve the green lock, the first step also involved observing and exploring the environment to find an encrypted code in the trash bin. Decoding required the use of the Alberti Disk, which associated numbers with letters, leading to a specific page in a biology book that was chained up (Puzzle C). To open the book's lock, participants had to find three transparencies scattered around the room and overlay them correctly. The combination of the images formed a numeric sequence, which would be used to open the lock (Puzzle D).

Inside the book, the player found highlighted information about the Body Mass Index (BMI), accompanied by the hint: 'the mirror is the key'. This information directed the participant to the scientist's notebook, which contained an explanation about the relationship between BMI, the description of tests involving a chemical substance, and the victims subjected to these tests, each identified by a five-letter code (Puzzle E). Additionally, a mirror was hidden in one of the desk drawers (Puzzle F). Using this code and both the hint and the mirror, it would be possible to open the cryptex.

Upon opening the cryptex, participants would find a paper riddle describing a gas used in fertilizers and anaesthetics, known as ‘laughing gas,’ but also characterised by its role as a greenhouse gas and an agent of ozone layer depletion. In this case, the atomic masses of the chemical elements that form nitrous oxide (N_2O) would provide the correct combination to open the green lock (Puzzle G). To understand the players' experience, the following section will be dedicated to discussing the analysis of results obtained through the questionnaires and interviews conducted with the participants.

4. Impact Assessment

The escape room sessions took place on Thursdays, Saturdays, and Sundays, with six sessions per week, over three months of activity. A total of 98 groups participated, amounting around 360 people. After each session, participants were invited to complete the post-game questionnaire individually. A total of 211 questionnaires were collected. To enrich the analysis, semi-structured interviews were conducted with five participants from different groups who returned to the Scientific Escape Room, aiming to understand the advances in the applied knowledge and to identify possible impacts after the experience.

First, we'll briefly discuss the respondents' profiles, which indicates a predominance of young adults, with 66.5% in the 20–29 age group, followed by 16.2% between 18 and 20 years old, 11.7% between 30 and 39, 1.7% between 39 and 40, and 3.9% over 40 years old. Regarding education, most players were attending higher education (51.4%), 16.2% had completed higher education, 9.5% had incomplete postgraduate studies, 13.5% had completed postgraduate studies, and 8.4% had completed secondary education. Data on participants' gender identity indicate a predominance of cisgender women (55.3%), followed by cisgender men (41.3%), non-binary individuals (1.7%), and one transgender man (0.6%), while 1.1% of participants preferred not to identify themselves. Regarding self-declared race/colour, there was a predominance of white participants (74.3%), followed by mixed-race (18.4%) and Black participants (7.3%). Although the activity reached participants with different profiles, there was a predominance of young adults and individuals currently in higher education, which may be related to the Science Center's presence in the university environment and the publicity made through university-affiliated channels.

Regarding the overall experience of participants in the Scientific Escape Room, we analysed the question, ‘*Tell us something you've learned and/or developed during your participation in the Escape Room*,’ which received 207 valid responses. After analysis, these were classified according to a priori categories corresponding to the five GLO dimensions, based on Content Analysis (Bardin, 1977). The research did not aim to generate emergent categories, but rather to identify which GLO dimensions were evidenced in the participants' accounts. To guide the coding, meaning units were defined for each category, inspired by the content indicators proposed by Hooper-Greenhill (2007), presented in Table 1. The ATLAS.ti software (ATLAS.ti Scientific Software Development GmbH, 2020) was used to assist in data organisation, coding of meaning units, and systematization of occurrence frequencies associated with each category. Coding was carried out by the first author and reviewed by the supervising professor to discuss ambiguities and refine data classification.

Table 1: Categories and analysis indicators adopted for data coding. (Table adapted from Hooper-Greenhill (2007), p. 51)

GLO Categories	Indicators Used for Coding
Knowledge and Understanding	Mentions of scientific concepts, phenomena, school content, or explanations related to science.
Skills	References to logical reasoning, critical thinking, communication, teamwork, organisation, emotional control, or manipulation of objects.
Attitudes and Values	Expressions of self-confidence, empathy, tolerance for diverse ideas, or self-reflection.
Enjoyment, Inspiration, and Creativity	Accounts of fun, imagination, creativity, curiosity, or lateral thinking.
Action, Behaviour, and Progression	Future intentions for action or changes in behaviour.

Next, the records in each category were quantified, and those considered most representative were selected. It is noteworthy that responses could be assigned to more than one category. To preserve anonymity, participants were identified as “P1”, “P2”, and so on.

Table 2: Analysis of the open-ended question from the questionnaire “Tell us something you learned and/or developed during your participation in the Scientific Escape Room.” (Table prepared by the authors)

GLO Categories	Examples of Most Representative Responses	Frequency of responses
Knowledge and Understanding	P43: ‘I learned to use UV light more.’ P74: ‘I recalled knowledge about the periodic table.’ P91: ‘Not all coins are magnetic.’ P160: ‘N ₂ O gas is used as laughing gas.’	28
Skills	P2, P19, P21, P23, P33, P38 (and others): ‘Teamwork.’ P6, P15, P24, P32, P35, P50 (and others): ‘Logical reasoning.’ P19, P41, P61, P62, P104, P105, P110, P184: ‘Patience.’ P30: ‘I discovered that each lock has a specific way to open.’ P83, P184: ‘Staying calm.’ P153: ‘I developed my group communication and objectivity skills.’	84
Attitudes and Values	P13: ‘Ability to trust other people.’ P20: ‘Listening to and accepting other participants’ opinions as valid attempts to solve the puzzles.’ P65: ‘That I get stressed when I don’t know things.’	30
GLO Categories	Examples of Most Representative Responses	Frequency of responses
Enjoyment, Inspiration, and Creativity	P98: ‘Creativity/Imagination.’ P108: ‘I just had fun.’ P181: ‘Imagination, with wild theories behind the experiments and connections between the elements in the room.’ P126, P135, P187: ‘To think outside the box.’	38
Action, Behaviour, and Progression	P71: ‘The escape room encouraged me to look at problems from different perspectives, seeking creative solutions for issues that may at first seem too difficult or complex. Therefore, I developed a more curious outlook.’ P94: ‘I believe it helped me try to be more observant.’ P97: ‘I learned that I need to work more as a team...’ P169: ‘To try to deal with problems under pressure.’	23
Non-conclusive responses	P196: ‘I haven’t identified anything yet.’	7

As can be seen in the table above, all the dimensions proposed by the GLO were, to some extent, reflected in the Scientific Escape Room experience, allowing the vast majority of responses to be categorised. However, it is worth noting that the voluntary and non-formal nature of the activity contributed to brief or less detailed questionnaire responses due to post-activity fatigue and the absence of formal academic requirements or direct external rewards (Hooper-Greenhill, 2007). To complement these findings, semi-structured interviews were conducted to provide a deeper analysis of the GLO dimensions evidenced by the participants.

Regarding the *Knowledge and Understanding* category, the responses suggest that the experience fostered not only the acquisition of new information but also the integration of different types of knowledge mobilised during the activity. The *Skills* category was the most frequently evidenced, indicating the integrated development of cognitive, social, emotional, and physical skills and reinforcing the potential of GBL to foster competencies such as critical thinking, creativity, collaboration, and communication (Qian and Clark, 2016). The prominence of teamwork may also reflect the collaborative nature of escape rooms. Unlike competitive Game-Based Learning approaches, escape rooms require participants to communicate, share knowledge, and solve problems collectively, which may explain the frequent references to collaboration in participants' responses.

Participants' responses in the *Attitudes and Values* category indicate the development of respect for and consideration of different perspectives, aspects directly associated with empathy and tolerance for diverse ideas (Hooper-Greenhill, 2007). In the *Enjoyment, Inspiration, and Creativity* category, reports describing the activity as enjoyable indicate that the game provided experiences of enjoyment, a central element of this dimension, particularly in non-formal contexts where engagement tends to occur more spontaneously. Creativity also stands out in the participants' accounts, reflecting a creative process associated with imagination and immersion in the narrative—features expected in escape room games.

Finally, the *Action, Behaviour, and Progression* category refers to changes in how individuals perceive, interpret, or respond to an experience, which may be reflected in immediate outcomes or future developments (Hooper-Greenhill, 2007). The responses indicate changes in how participants perceived and approached problems, behavioural changes, and greater recognition of the value of teamwork. Overall, the findings suggest shifts in perspective and intentions for action that may develop into more lasting transformations, although it is not possible to determine whether these changes will persist, as this dimension is difficult to assess in the short term.

To further explore the Knowledge and Understanding dimension, we focused on the interview question: *'What science knowledge did you need to use to solve the challenges?'* This question sought to examine how participants recognised and named the knowledge involved, since Hooper-Greenhill (2007) considers the ability to provide information, name objects, people, or places, and explain concepts or scientific fields to be an indicator of knowledge. Understanding, in turn, develops when learners relate new information to their existing knowledge through a personal process of meaning-making.

The interviews demonstrate the mobilisation of knowledge from different disciplines, particularly Chemistry, Physics, and Biology. Responses such as *'UV light'* (R2), *'logical reasoning'* (R4), and *'the fluorescence and periodic table'* (R5) indicate participants' ability to identify concepts and recognise specific scientific phenomena. The data also suggest that participants established connections between the game challenges and different scientific disciplines, as illustrated by the following statements: *'mainly chemistry knowledge, finding the symbols on the periodic table, that last one about N₂O, and you can also think about physics, about magnetism, when we used the magnet on the coins (...)'* (R1); *'I saw things from chemistry, biology, and physics. There's the magnet, which relates to physics; biology because of the BMI clue in the biology book; and chemistry because of the final puzzle involving atomic mass'* (R3).

Evidence of deeper understanding also emerged when participants related prior knowledge to new situations while solving the challenges. This is reflected in descriptions of trial, inference, and connection. For example, R2 described exploring different surfaces with UV light until identifying its function in the puzzle, illustrating a process of experimentation. The same participant also described connecting the clues with the mirror: *'That part with the mirror... I spent a long time thinking about it, you know?'*

Beyond knowledge acquisition and problem-solving, this study also sought to understand the impact of the Scientific Escape Room on participants. To this end, we analysed the interview question: *'Would you recommend the Scientific Escape Room to others? Why?'* The willingness to recommend the activity, together with the reasons provided, offers valuable insights into the value participants attributed to the experience. The responses reveal an overwhelmingly positive evaluation, reflected in a strong willingness to recommend it. This recommendation was mainly associated with the enjoyable and social nature of the activity, as highlighted by R1, who valued the opportunity to reconnect with friends, and by R3 and R4, who emphasised that the experience was fun, distinctive, and accessible: *'I would recommend it to everyone; it's easily accessible, it's fun, it's different, and it's free.'* (R3).

Moreover, participants emphasised the positive feelings generated throughout the game, such as the *'very good feeling of victory'* (R2) and the satisfaction of successfully completing the challenges (R5), highlighting the

experience's potential to promote emotional engagement. Beyond entertainment, the responses also reveal other important learning dimensions. Inspiration is evident when R2 mentions recalling scientific knowledge that had not been used for a long time, suggesting that the activity rekindled interest in science and reconnected participants with scientific concepts. This clearly reflects the *Enjoyment, Inspiration, and Creativity* dimension of the GLO framework. Together, these findings indicate that participants' recommendations were based not only on the enjoyable nature of the activity but also on the meaningful learning experience it provided, combining enjoyment with cognitive engagement.

5. Study Limitations

This study has some limitations that should be acknowledged. First, the sample is subject to selection bias, as the intervention took place at a university science center, favouring participation by individuals with closer ties to the academic environment. Furthermore, the immediate collection of data may have been influenced by the novelty effect generated by the immersive nature of the game. Therefore, future longitudinal studies are needed to examine the long-term retention of the Generic Learning Outcomes (GLOs).

6. Conclusions

Although exploratory, this study provides evidence of the potential of educational escape rooms both as a science communication strategy and as a university outreach initiative by enabling participants to engage with science through playful and interactive experiences, thereby strengthening the relationship between the university and society. The Scientific Escape Room project combined scientific concepts with an engaging narrative to provide participants with an active, immersive learning experience centered on solving scientific challenges. Regarding evaluation, the use of the Generic Learning Outcomes (GLO) framework proved to be a valuable approach for identifying different dimensions of participants' experiences. The findings not only demonstrate that school-level scientific knowledge was mobilised during the activity but also highlight the cognitive, social, and emotional dimensions involved in participants' learning experiences.

Overall, this study reinforces the growing evidence supporting the integration of game-based learning and science communication. It also contributes to the ongoing discussion on improving evaluation frameworks for educational initiatives developed in non-formal learning environments.

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Ethics Declaration: This research was approved by the Human Research Ethics Committee of the Federal University of Juiz de Fora, under opinion number 90507225.1.0000.5147. All participants signed the Informed Consent Form for participation in the research.

AI Declaration: Grammarly was used to support translation between Portuguese and English and to improve language clarity. ChatGPT (OpenAI) was used to assist with reference formatting.

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