Journal on Interactive Systems, 2026, 17:1
ISSN: 2763-7719 • doi: 10.5753/jis.2026.7357

Research Paper

Evaluating Customizable Serious Games for Scientific Dissemination through Thematic Analysis

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Abstract. *Background:* Serious games are a category of games developed with goals beyond entertainment, such as knowledge transfer and skill development. These games have already been proven as a successful means of knowledge transfer and scientific dissemination. They aim to share knowledge by engaging players through the ludic elements of a game. Despite that, the time, effort, and knowledge required to fully develop a game are not trivial and may limit the possibility of different researchers sharing their research through them. Based on this, it is possible to see benefits in the development of a straightforward tool allowing researchers to create serious games related to their specific research. *Purpose:* This study aims to evaluate a simple tool for creating simple games based on scientific research from the players' perspective and provide recommendations, as well as gauge the interest of the players in the research shared through the games. The goal is to provide information on the players' needs and preferences for games with the purpose of scientific dissemination. We hope with this research to promote interest in scientific content and provide recommendations for other researchers interested in using serious games as a means of scientific dissemination. *Methods:* The evaluation was realized through 20 structured interviews with students of a game development undergraduate course. Each participant played three different minigames customized to share three different researches: *Article*, *Data*, and *Categories*. These interviews were recorded and transcribed to be analyzed through the process of thematic analysis. *Results:* After the realization of thematic analysis, the selected quotes were separated into 83 different codes. These codes were then grouped into one of eight defined themes: Game type, Positive perception, Negative perception, Scientific dissemination, Suggestions for the games, Design accomplishments, Design flaws, and Theme impact. Participants reacted positively to the games format of emulating simple daily games and the purpose of sharing research results, while providing valuable insight into how to improve the games. Results also showed that the games did promote interest and curiosity from the participants about the shared studies. *Conclusion:* The interviews showed that there is interest from the players in this type of serious game. They also provided evidence that these types of games can promote curiosity in scientific content and even the active pursuit of knowledge. This research shows that this approach to scientific dissemination can stimulate interest while broadening the reach to different audiences by lowering the technical barriers that researchers would have to go through to make a game about their scientific results.

Keywords: Serious Games, Customizable Games, Thematic Analysis

Edited by: Flávia Garcia de Carvalho | **Received:** 05 January 2026 • **Accepted:** 06 May 2026 • **Published:** 16 May 2026

1 Introduction

Serious Games refers to games in which the main goal is not only entertainment, but also knowledge transfer or the development of specific skills [Abt, 1987]. This category of games has a growing and successful history in the academic environment [Zhonggen, 2019], using the ludic elements of a game to train and educate [Abt, 1987; Ravyse *et al.*, 2017]. In particular, a growing application of Serious Games in this context is games as a means of scientific dissemination [Gómez-Maureira *et al.*, 2022]. Games with this purpose aim to share scientific results with the general public, using the interactivity of the medium to reach an audience that would not interact with the results of these studies in other ways.

The recurring limitation of this approach to scientific dissemination is the knowledge, time, and skills required to develop a complete game. The development of a game requires substantial specialized technical knowledge and significant time investment, including coding (in the case of digital games), art production, and game design. Additionally, many of the games reported in the literature are not updated after the research has been completed. In this context, it is possible to infer the possible benefits of a simple tool that would allow teachers and researchers to easily customize and create their own serious game according to their research or academic field.

This exploratory study aims to evaluate this kind of tool from the players' perspective and provide recommendations, as well as gauge the interest of the players in the research shared through the games. To do this, we gathered 20 people enrolled in a Game Development undergraduate program at PUC Minas. Each of the participants played three fully customizable minigames, based on simple games like the *New York Times Wordle*, each sharing a different scientific research, and participated in a recorded interview about their experiences. The content of these interviews was transcribed and analyzed through a thematic analysis to understand their perspectives and opinions, as well as identify patterns [Ahmed *et al.*, 2025], allowing us to understand how these games

succeeded or failed in their goal of raising interest in the shared research and if there is room for further growth on this exploration of Serious Games.

The expected contributions of this study include advancing the understanding of games as a medium for scientific dissemination, specifically, simple, customizable minigames. It investigates whether these games achieve their goal of sharing scientific knowledge, as well as how they can be improved. This work may also promote the development of more Serious Games with the purpose of scientific dissemination and sharing scientific results, possibly making more individuals interested and informed about scientific knowledge.

This paper is organized into four additional sections. Section 2 presents background knowledge required for the comprehension of this work and related works to this study. Section 3 delves deeper into the methodology utilized in the thematic analysis, the interviews, and the minigames played by the interviewees. Section 4 is about the results found in the thematic analysis of the 20 interviews. Section 5 contains the discussion of the found results. Section 6 presents the recommendations of desirable characteristics of customizable serious games as means of scientific dissemination found in this study. Section 7 is the conclusion of this study, along with recommendations for future work.

2 Background

This section is organized in four different subsections. The first subsection explains the definition of Serious Games. The second presents the concept of scientific dissemination. The third presents the methodology of thematic analysis. The fourth subsection presents published works related to this study.

2.1 Serious Games

A game is an optional activity in which one or more players pursue objectives within defined rules that make this activity possible [Suits, 1967; Michael and Chen, 2005]. Games can be conducted through various modalities, including in-person interactions, digital platforms such as mobile phones and computers, and physical formats such as tabletop games. They also can serve different purposes, for example: entertainment, training and education.

Serious Games is the scientific term referring to games on which the main purpose is not to entertain, but knowledge transfer, training and education [Abt, 1987]. This does not imply that serious games cannot incorporate elements of entertainment; rather, such elements are not their primary objective. For example, a physician may use a game-based simulation to learn how to approach a surgical procedure, not for entertainment purposes, but to enhance professional performance [Michael and Chen, 2005].

Serious Games have been successfully utilized in different ways: as an educational tool [Fiore *et al*., 2014]; as means of citizen science [Miller *et al*., 2023]; scientific dissemination [Gómez-Maureira *et al*., 2022]; medical training [Jackson *et al*., 2020]; disaster prevention [Tsai *et al*., 2020]; professional knowledge transfer [Ariffin *et al*., 2010]; among others.

2.2 Scientific dissemination

Although there is interest in scientific knowledge among Brazilians from diverse social classes and backgrounds [Castelfranchi *et al*., 2013], there remains a perception that scientists use language that is difficult to understand. This may contribute to a sense of distance between science and the public Massarani *et al*. [2024]. As people encounter scientific knowledge through different means, such as social media, the development of diverse and innovative approaches to science communication may be beneficial [Massarani and Moreira, 2016].

Scientific dissemination is the process of sharing findings and results through different methods with one of three goals: educate, presenting scientific knowledge in accessible and understandable ways to the general public [Kuo and Chuang, 2016]; civic, promoting the construction of an informed public opinion about the impacts of scientific development [Vergara *et al*., 2024]; and popular mobilization, aiming to raise awareness of the general population on scientific matters, promoting their participation in decision making processes involving public policies [Albagli, 1996].

There are a lot of methods for scientific dissemination, which vary from case to case based on the target audience, such as if the content targets the general audience or other researchers; resources available to the researchers; and the main goals of the study or publication. Examples found in the current literature of different methods of scientific dissemination include: scientific publications [Fawcett *et al*., 2020], social media [Velazquez-Solis *et al*., 2022], serious games [Signa *et al*., 2022], videos [Bourne and Chalupa, 2008], and citizen science [Vergara *et al*., 2024].

Scientific publications are the most established and formal means of disseminating scientific knowledge or research among other researchers, ensuring the research credibility through peer-review processes. They are effective in sharing results within the academic community and communicating detailed methodologies, frameworks, and results. However, technical language, restricted access in some cases, and limited reach beyond specialized audiences may affect broader public engagement [Beck *et al*., 2019].

Social media platforms have emerged as a means of fast communication of research findings to diverse and non-specialist audiences. They facilitate interaction between the public and researchers, contributing to increased visibility and social impact of the shared work. The problem with this approach is that higher education institutions and researchers need to propose dissemination strategies aligned with the medium, achieving the goal of reaching a wider audience [Said-Hung *et al*., 2024].

Serious games represent an interactive approach to scientific dissemination. This method has shown potential to increase motivation, engagement, and retention of knowledge [Signa *et al*., 2022]. Serious games promote experimental learning and active participation, which are often lacking in traditional dissemination formats. However, their development typically requires significant time, specific knowledge, and resources.

Videos and other audiovisual resources, such as podcasts, have become increasingly popular due to their ease of access and ability to combine visual, auditory, and narrative elements.

They can share scientific knowledge with general audiences by presenting scientific information in a more intuitive and engaging manner. They are well-suited for online dissemination and educational context [Sentanin *et al*., 2023], although producing high-quality videos can be time-consuming and require resources. Also, the need to simplify the scientific content may limit the depth of the information conveyed.

Another approach to Scientific dissemination is Citizen Science. Citizen science refers to the active involvement of members of the general public in the process of scientific research, as a means to democratizing knowledge. Their participation may include data collection, analysis and interpretation, while in collaboration with researchers [Bonney *et al*., 2016].

2.3 Thematic analysis

Thematic analysis is a qualitative research method in which themes and patterns can be easily identified by the researcher on a set of data [Boyatzis, 1998]. Usually, it compresses raw and extensive data into a smaller and focused structure, allowing the researcher to compare and identify the data more easily [Denscombe, 2017]. This methodology is considered appropriate for studies that aim to infer knowledge through interpretations of descriptive data [Alhojailan and Ibrahim, 2012].

The process of thematic analysis starts with a group of text-based data. Relevant quotes found in these texts are highlighted and defined by a *Code*. Quotes with similar intentions can share the same code. After this is done to all the available data, these codes are reviewed and, if possible, merged or deleted. In the next step, these codes are grouped in similar themes. Each theme is further analyzed according to the specific research [Alhojailan and Ibrahim, 2012].

2.4 Related work

Related works to this involve studies on which serious games were employed with the goal of scientific dissemination or evaluated through thematic analysis as a means to further understand their efficacy with their target audience. Some of them also aim to ease serious games applications by researchers to promote the scientific engagement of the general public. The comparison between this work and the featured related works can be seen in Table 1.

Kuo and Chuang [2016] created a virtual space for students, teachers, and the general public, on which serious games and gamification systems are used as means to promote new scientific research and share their results. The platform was developed specifically to be used in the National Pingtung University of Science and Technology (NPUST) and features different minigames and reward systems. Although similar, this online platform is limited to NPUST and lacks tools for the creation or customization of serious games.

Fitzgerald and Ratcliffe [2020] developed a study to evaluate the use of serious games in the treatment and recovery of mental illness through thematic analysis. Published papers on the subject were aggregated and selected to be analyzed. Through this method, they were able to further understand the weaknesses and strengths of serious games for this purpose. Although their paper studies serious games with a different goal, their methodology is similar, as is their goal of evaluating serious games through it.

Recently, Signa *et al*. [2022] developed a serious game called *Bubblemumble*, whose main objective is to share results of a specific scientific research with students in elementary school, in an easy and fun way, to promote their understanding and engagement on the subject. Their research studies the application of serious games with the purpose of sharing specific research, not a customizable game, and focuses only on elementary school students instead of the general public.

These studies present a growing interest in the usage of serious games as a means of scientific dissemination, and a desire to ease the creation process of games with this purpose.

3 Methods

This study used a qualitative approach that involved 20 structured interviews analyzed through thematic analysis. It can be classified as an exploratory study, as it seeks to gain initial insights and deepen understanding of the investigated phenomenon without a pre determined hypothesis [Gil *et al*., 2002]. The methodological steps and procedures can be seen in Figure 1 and are described in detail in the following subsections.

3.1 Participants

For this study, the goal was to investigate whether and in what ways customizable games can function as a medium for scientific dissemination. Thus, for the interviews, we invited every student from a Game Development undergraduate course, as most of the students in the field would probably already be players of digital games and could provide insightful feedback for the games, their approach to sharing the scientific content, and their design. In total, 20 students from the course accepted to take part in online interviews. It is worth noting that none of the researchers, either involved in this study or in the studies presented through the games, have any connection to the participants.

3.2 Materials

Before answering the interview questions, participants played three simple, customizable minigames. These games were developed in Unity and made available through a web browser. All three were inspired by daily web-based games such as the New York Times Wordle, with the intention of creating lightweight, repeatable experiences accessible to a wide audience. Their only varying component was the scientific content embedded in each game.

All games can be customized through the game editor, allowing researchers of different fields to share their research through them. They were based in tools such as *Google Forms* in an attempt to facilitate the process of creating a game through them.

In the first minigame, titled *Article* (Fig 2), players receive the abstract of a scientific paper, in which all words are initially hidden. The objective is to uncover the title of the paper. Players do so by guessing words that may appear in the abstract or in the title. As correct guesses reveal additional portions of the text, players gain more contextual information. They may also use a “Reveal word” button if they become stuck, or choose to give up by clicking the “Answer” button, which leads to a results screen showing the full abstract and a

Works	Goal of the game	Customizable	Evaluation methodology
Kuo and Chuang [2016]	Scientific dissemination	Not customizable	Likert scale forms and Google analytics
Fitzgerald and Ratcliffe [2020]	Treatment and recovery	Not customizable	Thematic analysis
Signa *et al*. [2022]	Scientific dissemination	Not customizable	Likert scale forms
This work	Scientific dissemination	Customizable	Thematic analysis

Table 1. Comparison between related works

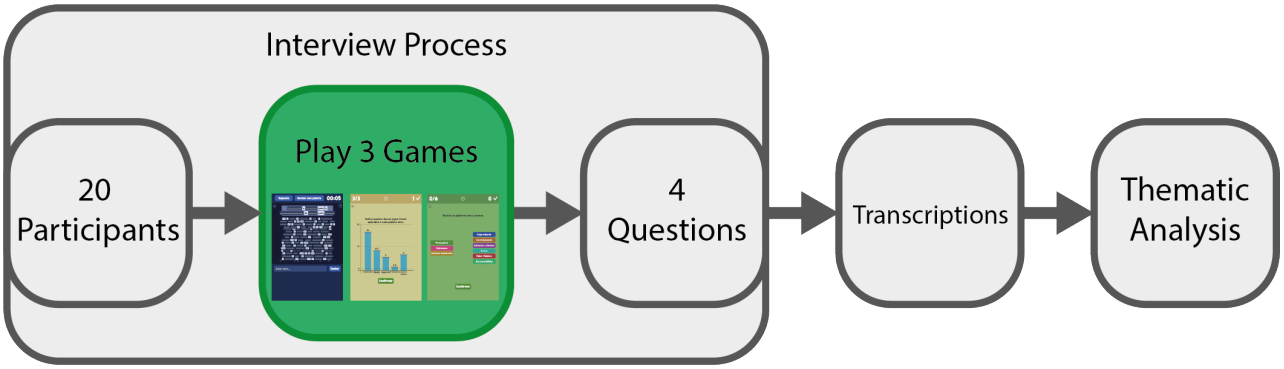

Figure 1. Steps of this study

link to the original paper. The game is completed successfully when the player uncovers the full title.

The *Article* minigame is fully customizable through the game editor, illustrated in Figure 3. This tool enables researchers and instructors to create tailored versions of the game by modifying the title and the text that the player uncovers during the game. Additionally, it allows the inclusion of a URL linking to the full research article, which becomes accessible upon completion of the game. For this study, the version of *Article* provided to participants was based on the work of Mol *et al*. [2021].

The second minigame, titled *Data* (Fig 4), is similar to a quiz. The Player is presented with a customizable number of questions, of which there are three types: Binary, answering yes or no question; Percentage, the Player is given a context and has to guess the percentage of something in the said context; And Graph, the Player is presented a column graph and a context, they have to guess the value of each column in the graph.

The *Data* minigame can also be customized through a game editor, which can be seen in Figure 5. Similar to the creation of a *Google Forms*, the researcher may click on the button to add a new question and choose between the three options. All options allow researchers to add their own context to the question and edit results according to their own research. The version of *Data* provided to participants was based on the work of Machado and Costa [2019].

The third minigame is titled *Categories* (Fig 6). In the game, the Player is presented with two columns with different words and has to link the words related to each other. The Player wins if they guess correctly which words are related.

Categories can be customized through an editor, illustrated by Figure 7 and Figure 8. First, in the Categories tab, researchers add the terms found in each column. Then, in the Connections tab, they define the connections between the added terms. The version of *Categories* provided to the participants was based on the work of Pereira and Ckagnazaroff [2021].

3.3 Data collection

We conducted individual interviews with each of the 20 participants. The content of the interviews was reviewed and approved by an ethics committee. After reading the Informed Consent Form, the participants played the three games in the order presented in this paper: first, *Article*; second, *Data*, and third, *Categories*. After playing the three games, the participants answered four questions:

1. Did you have fun with the games? Why?
2. How did you feel in relation to the content shared through the games?
3. What would you change to make the games better? Why?
4. How would you improve the player's engagement with the scientific content?

These interviews were recorded and fully transcribed.

3.4 Data analysis

After the 20 interviews were fully transcribed, the thematic analysis started. Thematic analysis is a widely utilized method for analyzing qualitative data with the purpose of identifying patterns within the collected data Ahmed *et al*. [2025]; Braun and Clarke [2006]. The proccess of thematic analysis in this research followed an inductive approach, on which codes and conclusions were defined based on the answers given by the participants. The transcriptions of the interviews were uploaded into an *Atlas.ti* project, on which all the analysis process was conducted. The interview participants identities were removed during the transcription process, changing every mention of their name to **P1-P20**. After analyzing the transcriptions, each possibly interesting answer or comment from the participants was given a code relating to their meaning or intention. An example of a code can be seen in Figure 9 and Figure 10.

Once all transcriptions were properly coded by a researcher, we revised the codes themselves. A different researcher was assigned to review the transcription coded by another. After this was done for all transcriptions, the codes, suggestions, and their quotations were reviewed by the whole

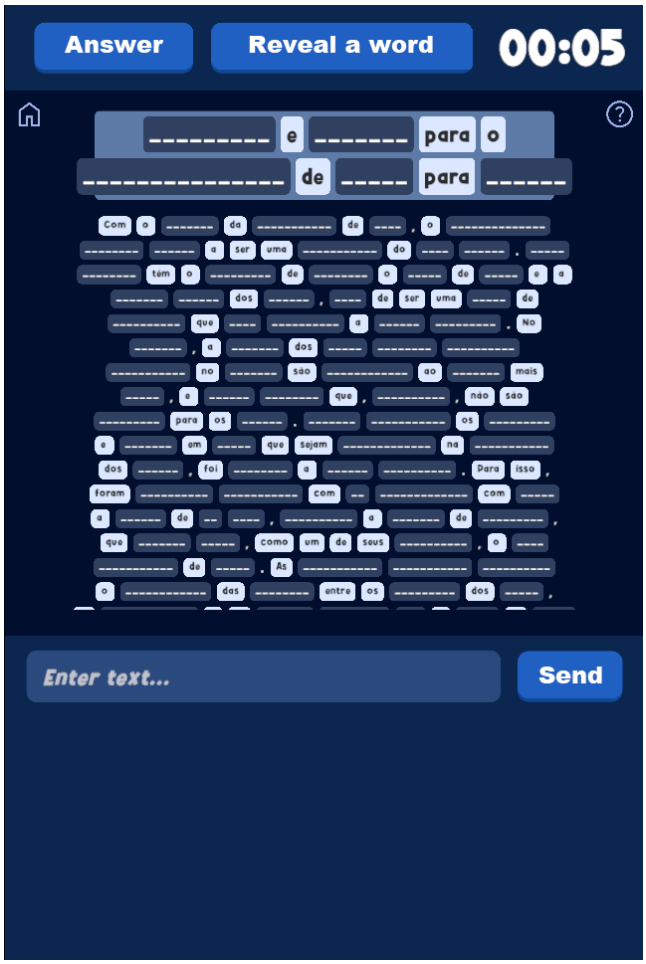

Figure 2. The first minigame, referred to as Article.

team during a meeting. The purpose of this revision is to merge codes that are too similar to each other or to remove codes that would not contribute to the study. Codes were merged or removed when the research team reached consensus. Then, in a different meeting, each of the remaining codes was given a broader theme, aggregating different codes to be analyzed.

4 Results

Twenty undergraduate game development students participated in individual interviews in which they played the three games and answered four questions. The interview sessions lasted between 30 minutes and 1 hour and 28 minutes, including the time spent playing the games, with most sessions lasting approximately 45 minutes. Their answers were analyzed through thematic analysis and resulted in 149 codes. Those were then filtered down, through merges if too similar or deleted if irrelevant. The process of thematic analysis realized in this research can be seen in Figure 11. After reviewing the codes, 83 different codes remained. These codes were organized into the following eight themes:

1. **Game type:** Positive comments related to the minigames format or positive associations to other games.
2. **Positive perception:** Positive comments related to a positive experience with the games.
3. **Negative perception:** Negative comments related to a negative experience with the games.

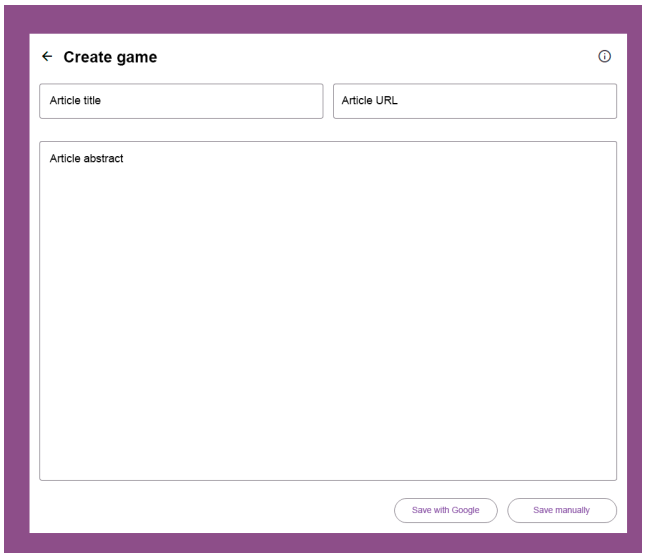

Figure 3. The editor of the Article minigame

4. **Scientific Dissemination:** Positive comments related to participants expressing interest in the scientific content shared through the game.
5. **Suggestions for the games:** Suggestions of new elements and changes to the games
6. **Design accomplishments:** Affirmations of successful execution and positive remarks regarding both the game design and the way players interacted with the games.
7. **Design flaws:** Problems found in the game design and in the interaction of the Players with the games.
8. **Theme impact:** Affirmations implying that Player interest in the research was impacted more by the research theme than by the three played games.

The following subsections will detail themes 1 to 6. Themes 7 and 8 present interesting insights; however, they are not relevant to the conclusions of this study. Theme 7, **Design flaws**, contains problems that are specific to the games developed, involving technical problems, Human-computer interaction (HCI) problems, and specific design flaws, for example, frustration with how the "Reveal word" button from the *Article* minigame works. Theme 8 contains affirmations in which participants expressed that their interest in the shared research was stimulated more by their previous interest in the shared content than the games. This is an interesting detail to note, but it is not central to the objectives of this study.

4.1 "Game type" theme

The "Game type" theme relates to positive comments about the three minigames format, including positive associations with other games, specially daily games like the ones that inspired the evaluated games.

In this theme, only one code was identified: **Thinking the Daily Games format is interesting**. Table 2 presents an example from this code.

Participants reacted well to the games format, making direct and positive comparisons to games used as reference for their development, like *Wordle* and the game *Termo*. Specifically, *Data* and sometimes *Categories* were compared to these daily games, while *Article* was compared to games like crossword puzzles. This feeling can be seen in Table 2 and

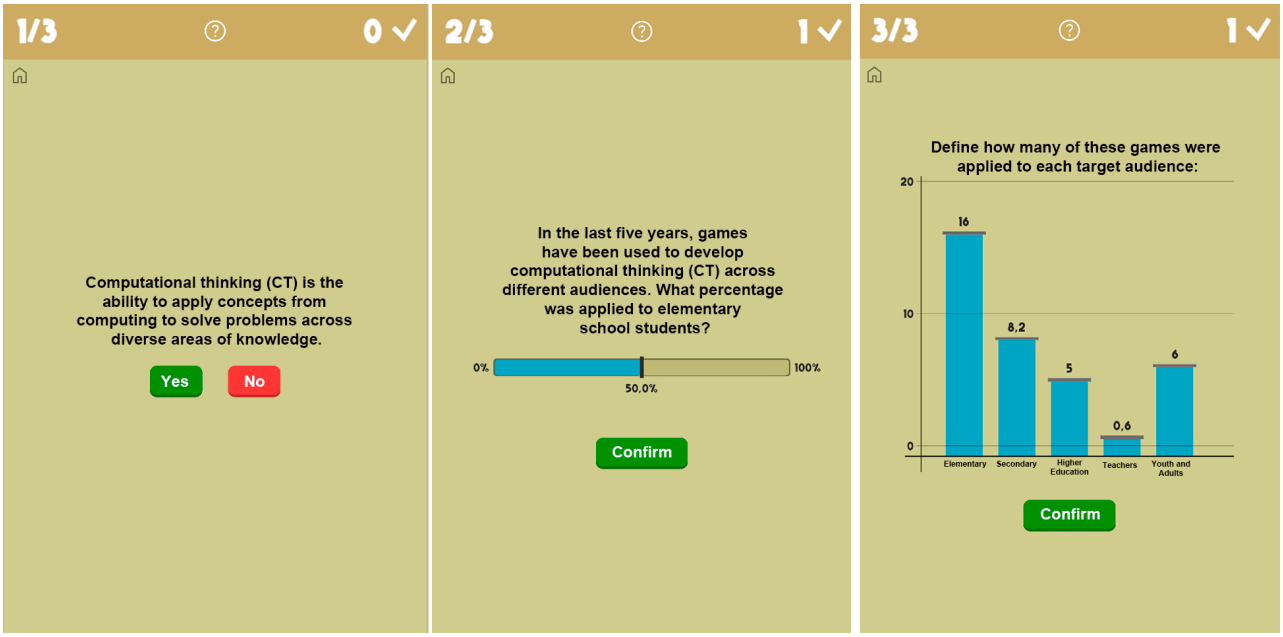

Figure 4. The second minigame, referred to as Data.

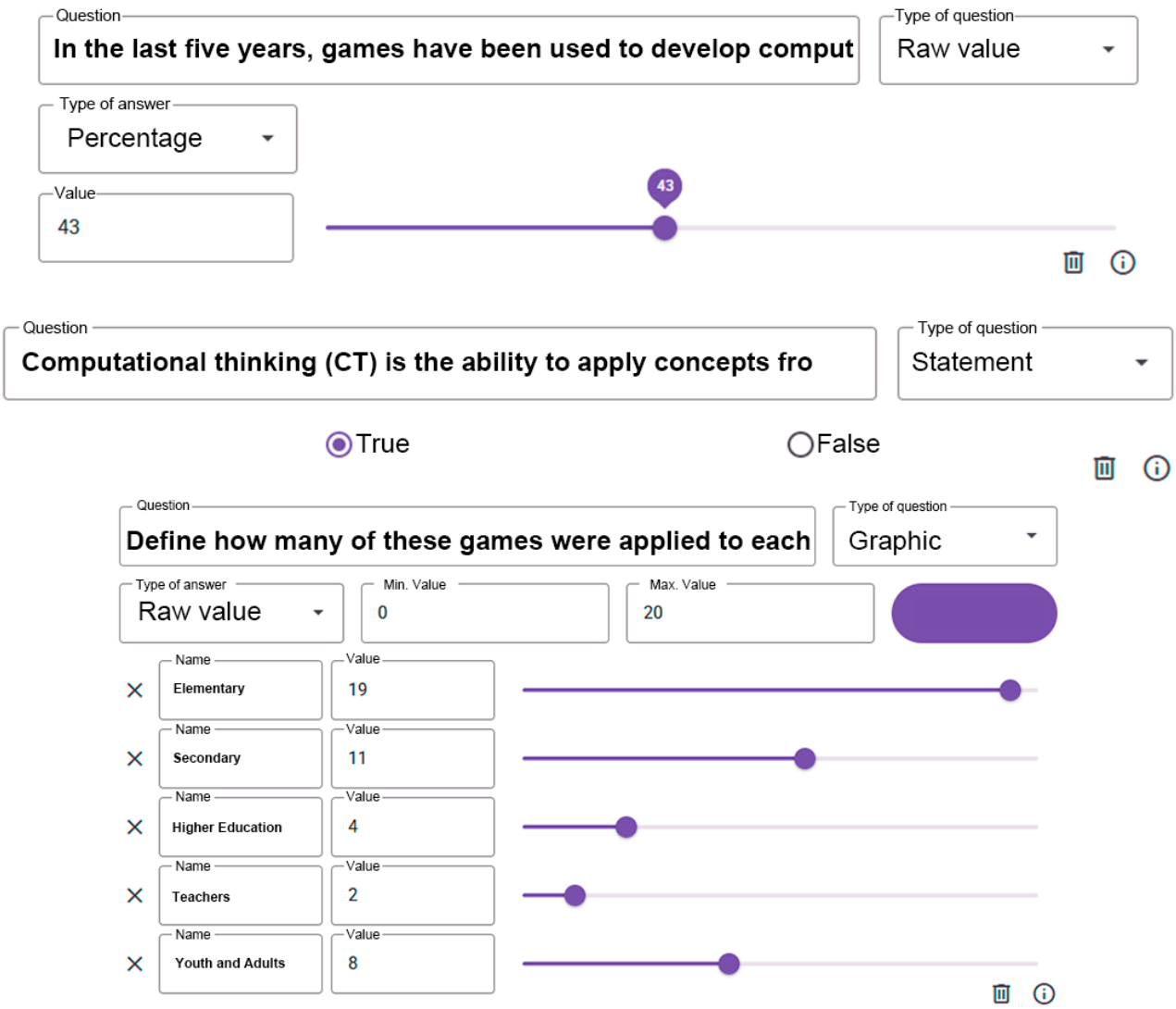

Figure 5. The editor of the Data minigame

Table 2. Codes from "Game Type" theme

Code	# quot.	# part.	Quote
Thinking the Daily Games format is interesting	14	9	"The second one[*Data*], I saw some potential in it, like that game *Wordle*, the puzzle, the one on which you have to guess a letter, like, if every day it was a different subject, I think I would play it every day." (P11)

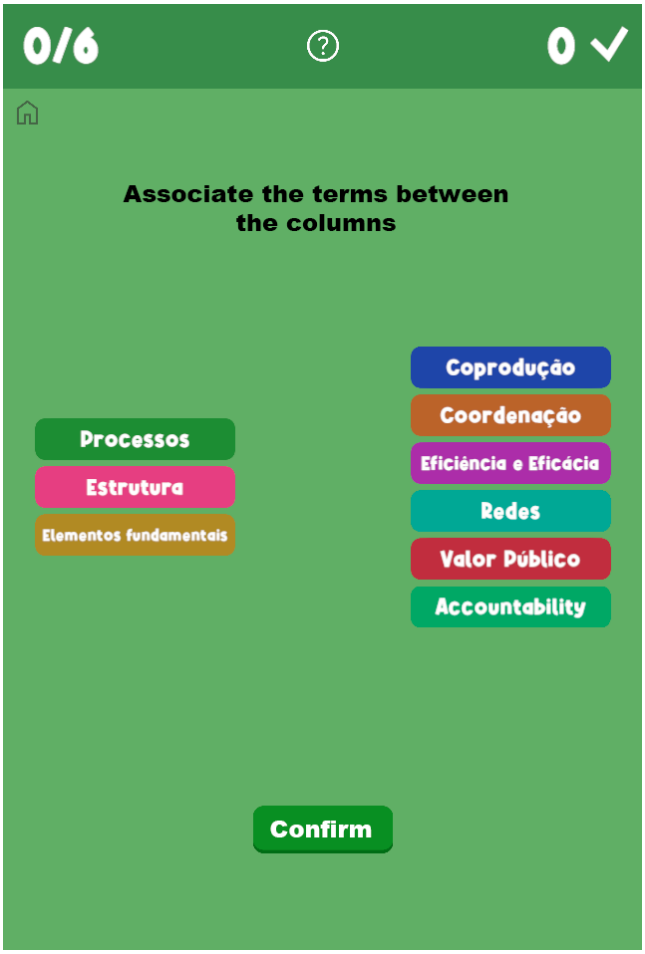

Figure 6. The third minigame, referred to as Categories.

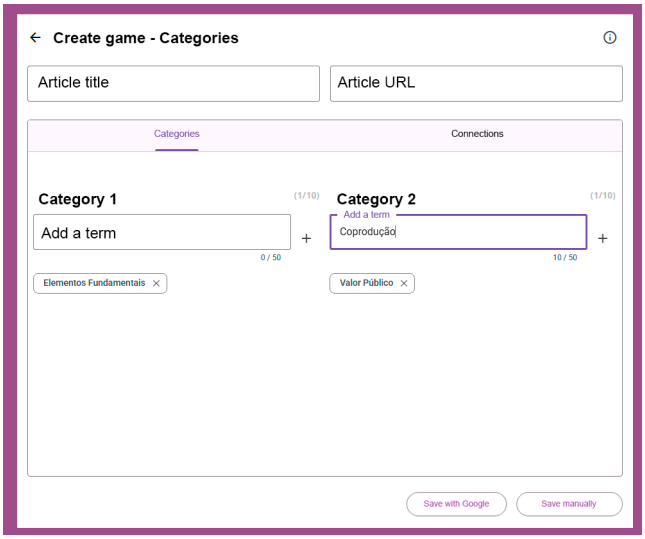

Figure 7. First step of the editor for the game Categories

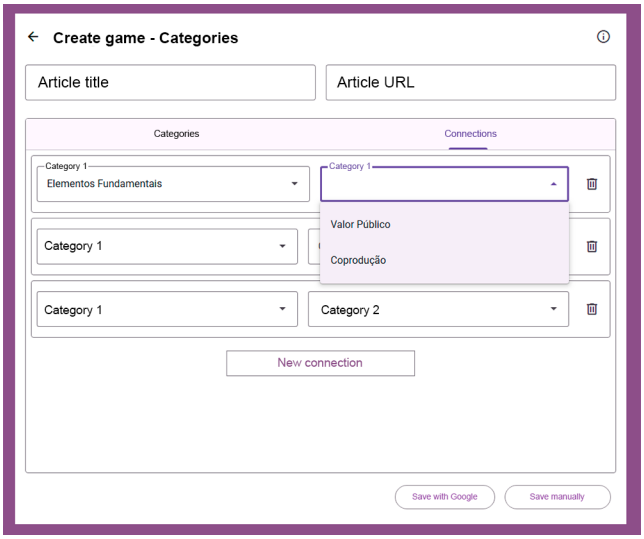

Figure 8. Second step of the editor for the game Categories

also in quotes like:

> "*I have played [and enjoyed] similar games, like Wordle*." (P6)

> "*They remind me of that type of game that got really popular recently. Like, to guess words, you know? Like Contexto, Wordle, Termo, this type of game, really.*" (P19)

> "*I think [I like] the first one [Article], I like this type of game, like crosswords, guess which word.*" (P12)

The format was also praised without requiring comparison. Some enjoyed them as minigames:

> "*The third one [Categories], I think the same as the second [Data], they are minigames and, in my opinion, were well made for this style [of game].*" (P11)

While the games were compared to daily games and newspaper games like crosswords, they were also compared to trivia games and apps like *Trivia Crack*:

> "*The second one[Data], I enjoy this type of game, like trivia, of guessing the answer.*" (P12)

> "*[I liked] The second one [Data], I think it was because, as I said, it reminded me of Trivia Crack.*" (P14)

4.2 "Positive perception" theme

The theme "Positive perception" encompasses comments of a positive nature regarding the experience of interacting with the minigames. The codes in this category indicate that the

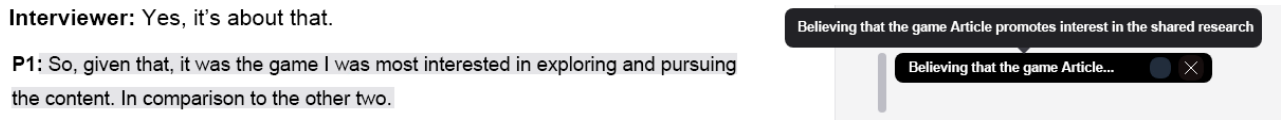

Figure 9. Example of quotation of the code Believing that the game Article promotes interest in the shared research

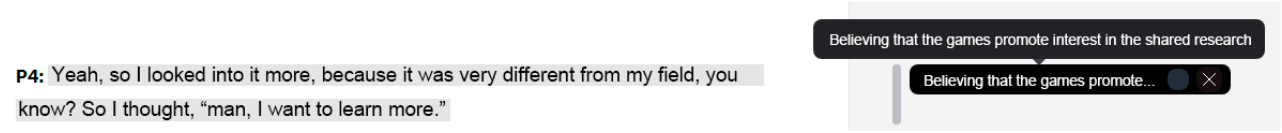

Figure 10. Example of quotation of the code Believing that the game Believing that the games promote interest in the shared research

games fulfill their objective concerning science communication, being perceived as easy, simple, and fun.

A total of 10 codes were identified within this theme, as shown in Table 3. These codes reflect the favorable views of participants after experiencing the games. The table also indicates the frequency with which comments belonging to each code appeared, the number of participants who made comments for each code, and a representative example of a comment.

As presented in Table 3, the reports suggest that each game, individually, managed to please the participants, resulting in a significant volume of positive comments about the experience. Furthermore, aspects related to the mechanical characteristics of the games were highlighted as positive perceptions, including simplicity, ease, and the possibility of reasoning about the answers. A participant's comment that well illustrates this point and is part of the code **Finding the Category game easier** is:

> "*It [Categories] was very simple, but it gave me this possibility of being able to reason out the answer.*" (P20)

Another highlight is the fun aspect provided by the games; several participants mentioned this point, as can be seen in the following comment:

> "*But it was fun overall, you know, I like these science content things, I even gave some answers on the form about it, but for me it's fun, you know? Learning more, so I think it's cool.*" (P4)

4.3 "Negative perception" theme

The "Negative perceptions" theme encompasses negative feedback expressed by participants regarding the three minigames analyzed. The accounts indicate perceptions of low appeal and engagement during interaction with the games, associated with expectations that were not fully met. The theme brings together different codes that reflect impressions of disinterest, lack of depth, and difficulties in sustaining engagement throughout the gameplay experience.

A total of 17 codes were identified within this theme. Table 4 presents illustrative examples of each code.

As presented in Table 4, the codes associated with negative perceptions of the games indicate that participants' experiences were marked by difficulties in engagement, frustration, and low interest in further exploring the scientific content presented. Negative feelings emerged both from the games' dynamics and their structure, including reports of excessive difficulty, simplicity perceived in a negative way, and the association of the games with evaluative formats, such as tests.

In addition to the quotations presented, other statements also reinforce these perceptions. One participant, for example, expressed frustration when describing the difficulty of the Article game, as observed in the **Feeling the difficulty in the Article game** code, stating

> "*And there were some words that were very difficult, like, there were some numbers, I think if I hadn't discovered that there was a number when asking for a hint, I would never have gotten it right*" (P12)

Another recurring issue, expressed both directly and indirectly, was the lack of stimulation of interest in scientific research. Participants reported that the games did not spark curiosity about the original articles, focusing more on mechanical aspects than on the scientific content itself. Examples of this can be seen in the codes **Stating that the Article game does not stimulate interest in research**, **Stating that the game Data does not stimulate interest in research**, and **Stating that the game Categories does not stimulate interest in research**, which are presented in the following quotations:

> "*I think that both the first [Article] and the third [Categories], by presenting the words in such a way [without further context], the first [Article] having to be guessed and the third [Categories] only being correlated, end up being just words and do not generate much interest in the content*" (P15)

> "*The second game [Data], as I explained, throws data in my face that do not encourage me to want to look at the article*" (P20)

Based on the number of quotations per code, it is possible to identify that the Data and Categories games concentrated most of the negative perceptions, particularly with regard to the lack of stimulation of interest in research and the overall negative evaluation of the experience. In addition, the Article game was frequently associated with frustration and disengagement due to the large amount of text presented.

4.4 "Scientific dissemination" theme

The "Scientific dissemination" theme aggregates positive quotes related to the participants' interest in the scientific content shared through the game. The comments included involve

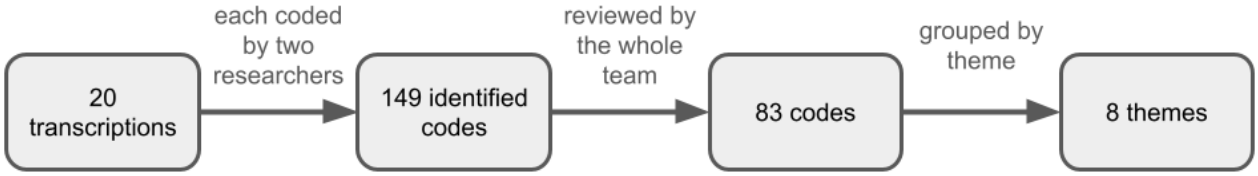

Figure 11. Steps of this study thematic analysis

Table 3. Codes From "Positive perception" theme

Code	# quote.	# part.	Quote
Enjoying the game *Data*	28	14	"Regarding the second [*Data*], I liked the dynamic of selecting the percentages and questions; I found them interesting." (P7)
Enjoying the game *Article*	26	13	"But I thought the first [*Article*] was cooler, it had a bit more reasoning." (P3)
Enjoying the game *Categories*	16	7	"This was my favorite [*Categories*], by far." (P1)
Having fun with games	8	7	"I had fun with the games, I found the idea interesting." (P2)
Thinking that the game *Article* fulfills its purpose	4	3	"It's not the type of game I like, but I know where it's coming from, so it works, it's cool." (P14)
Stating that the game *Categories* is simple in a positive way	3	3	"The last game [*Categories*] I think it's quite simple and it just works, in my opinion" (P20)
Finding the *Categories* game easier	2	2	"The third one [*Categories*], it has a bit of that too, but it's still easier for you to get something right" (P17)
Enjoying the games	2	1	"Ah, regarding the games, I liked them!" (P1)
Stating that the *Data* game is positively simple	1	1	"The last two [*Categories* and *Data*], because they are a bit simpler, I liked them more" (P2)
Enjoying the possibility of reasoning about the answers, in the *Categories* game	1	1	"This gave me the possibility to be able to reason out the answer" (P20)

positive feedback relating specifically to how the knowledge is shared through the games, shown interest in delving deeper into the research, and other positive comments about a greater proposal of games as a means to educate.

In this theme, 9 codes were defined. Table 5 presents examples for each of them:

- Believing that the games promote interest in the shared research
- Believing that the game Article promotes interest in the shared research
- Believing that the game Data promotes interest in the shared research
- Believing that the game Categories promotes interest in the shared research
- Appreciating the idea of a game as a means of providing information
- Finding the games educational
- Informing they opened the papers to read
- Thinking the games help update knowledge
- Stating that the games streamline access to research

As shown in Table 5, the three minigames achieved their goal of promoting scientific research, although to varying extents. The primary objective of the minigames was to offer different customizable formats suited to various types of research and to appeal to different types of players. The collected data reinforces that this design choice was effective.

Although the three games received positive feedback, it is noticeable that *Data* and *Article* were more effective in their goals than *Categories*. Each Player had their favorites, some enjoyed only one of the games or a different combination of them, but there are quotes that represent the general feeling of the data collected:

> "*The first one [Article] and the second one [Data], I found them more likely to spark interest in looking up the full paper*" (P7)

It is also important to note that a game's ability to convey knowledge and stimulate the player's interest does not necessarily mean that the game is enjoyable. This sentiment is illustrated in the following quotes:

> "*The first one [Article] was the one I enjoyed the least, but in relation to that [promoting interest in the shared paper] it was the one I was most interested in looking up after*" (P1)

> "*In the second game [Data] and the third game [Categories], it made me think about the article's topic, but I wouldn't say it was in a very playful way*" (P17)

4.5 "Suggestions for the games" theme

The "Suggestions for the games" theme is composed of 31 codes, involving different suggestions of new elements or changes to the games. These ideas of changes involve new ways to promote engagement, lacking elements in some game design choices and game presentation, and others. Examples of the most frequent codes can be seen in Table 6.

As seen in Table 6, most suggestions involve a lack of proper context on the scientific knowledge being shared through the games, leaving the players without the needed information when playing them. Although this is a general problem, its easy to see by the number of quotations and participants per code that the *Data* and *Categories* games are most at fault.

Even though most players had problems with the lack of context for the scientific content presented, some had problems in understanding how to actually play the games. This

Table 4. Codes from "Negative perception" theme

Code	# quote.	# part.	Quote
Feeling the difficulty in the *Article* game	21	11	"For me, it's a game that's extremely difficult to complete. " (P20)
Stating that the *Categories* game does not stimulate interest in research	16	10	"And I didn't feel much interest in going deeper into its [*Categories*] research, in looking at the article." (P7)
Stating that the *Categories* game is simple negatively	15	9	"The duration is also terrible, it's the worst game [*Categories*] of all, right? Its duration is minuscule." (P8)
Not liking the *Data* game	13	8	"In terms of enjoyment, because it's less challenging, I think it's less fun." (P18)
Finding the *Data* game simple negatively	12	8	"The biggest problem with the second game [*Data*] is its somewhat too short duration. It only has 3 questions, right? It's quite short. " (P8)
Not liking the *Categories* game	11	8	"The third one [*Categories*], I didn't like it very much." (P12)
Negative feelings about making mistakes in games	10	5	"I was frustrated because I actually made a mistake since I didn't know the information." (P14)
Stating that the *Article* game does not stimulate interest in research	8	5	"The first [*Article*] was a large block of text, so I was more concerned with getting the words right than actually understanding what was being said. I read some sentences that I was able to break down, but I was more focused on figuring out the context of the sentence and not so much on the meaning of the article." (P14)
Not liking the *Article* game	7	6	"The first [*article*] is very long, and it becomes frustrating." (P20)
Stating that the *Data* game does not stimulate interest in research	6	6	"It [*Data*] is less interesting in terms of making you want to be interested in the article" (P18)
Stating that they did not respond with confidence	4	4	"The player has no basis, and has nothing to, at least, uh, use as a basis to carry it out or to minimally reason about it, you know? He's going to have to kind of guess." (P3)
Awakening a negative feeling associated with a test	4	3	"The second [*Data*] and the third [*Categories*], I felt they were very much like exam questions." (P17)
Feeling the difficulty in the *Categories* game	2	2	"And the third [*Categories*], which was the game of making connections, was also quite difficult." (P4)
Finding the games simple in a negative way	2	2	"I think it's kind of hard to think about how to change [the games] because they are so small and simple." (P15)
Feeling frustration with the *Categories* game	2	1	"And these things start to get really mixed up, and it ends up being frustrating, because I already got feedback like, 'Oh, you got this wrong,' and then I still went on to get it wrong two more times after that, because I got confused looking at the words." (P9)
Not liking the games	1	1	"Honestly, I didn't [like it] very much, because it's not my type of game. " (P6)
Thinking that the player will quit the *Article* game quickly	1	1	"The first [*Article*], because it has a lot of text, I think the player will just click an answer and that's it." (P13)

can be seen in the **Suggesting the inclusion of a tutorial** code, with six quotations. The sentiment in this code is similar to the following quote:

> "*I would make the explanations on how to play the games clearer, be it a tutorial or something explaining better what has to be done, because I think it could be difficult for some people*" (P7)

Another common suggestion made, directly and indirectly, was about game presentation. As they were evaluated, participants felt the games were too serious and sober, lacking feedback elements that can help make a game more enjoyable and fun. Examples of this can be seen in the **Suggesting changes in the UI** and **Suggesting improvements to the presentation of the games** codes that can be read on Table 6, as well as the following quote:

> "*[Type of game] with a more interactive UI, cuter, that shines. I think just by doing that, things like that, cool ideas, it would still have the heavy didactic feel, but would be more enjoyable*" (P3)

4.6 "Design accomplishments" theme

The theme "Successful Design" addresses codes whose main focus is related to the design of the games, especially regarding aspects such as modern mechanisms that make the games more intuitive and replayable. Both are fundamental characteristics that contribute to sparking the user's interest in learning more about the presented article.

In this theme, two codes were identified, each containing one participant comment. Table 7 presents the relation of these codes and their respective comments.

Although the number of occurrences is limited, both codes presented in Table 7 show that the games have great potential to engage users and encourage them to seek more information about the article. As observed in the comments, the game arouses the desire to play repeatedly, which, in certain contexts of disseminating different works, stands out as a valuable characteristic.

5 Discussion

With the gathered results, it is possible to further understand the successes and failures of the games, the interest of the participants in this type of game, how they engage with the scientific content, and how this aspect of the games can be improved.

The format of the games was well accepted and praised by the participants. The three games were intentionally designed to be simple and replayable, working similarly to daily games like *Wordle*. The comparisons by the participants between the games were positive, and even in the **Suggestions to the games** theme, there were suggestions based on these games. In this experiment, the games format and main references were a success, meaning simple, replayable, and easy-to-understand games could be a worthwhile direction for other games promoting scientific content to different audiences. So, one defined recommendation is to provide simple,

Table 5. Codes from "Scientific Dissemination" theme

Code	# quot.	# part.	Quote
Believing that the game *Data* promotes interest in the shared research	20	14	"There were a lot [of results in questions of the *Data* game] that surprised me [...], so I was interested in the information when it was over. And to get to it I'd have to go to the paper, which is good, right? " (P9)
Believing that the game *Article* promotes interest in the shared research	19	12	"The first one [*Article*], its content is well explored, right? You have an abstract if the paper there, I think it is the best of the three in terms of exploring the paper" (P8)
Believing that the games promote interest in the shared research	10	6	"I found it very interesting, it entertains you and invites you to search for more knowledge on the subjects portrayed in the game" (P5)
Appreciating the idea of a game as a means of providing information	9	6	"It's a initiative that I found very, very nice. The base central idea is very great" (P17)
Believing that the game *Categories* promotes interest in the shared research	8	5	"I think the third game [*Categories*] was the one that most sparked my interest in the scientific paper" (P20)
Finding the games educational	3	3	"Because the games have an educational aspect, which is you are learning from them at the same time as you play" (P5)
Informing they opened the papers to read	1	1	"I opened them [the papers] to read later" (P19)
Thinking the games help update knowledge	1	1	"I found myself intrigued, I remember reading about that before and thought it [the knowledge] would still be the same as it was a few years back [...] Then I answered and saw it was different — that idea about always updating your knowledge" (P11)
Stating that the games streamline access to research	1	1	"I found all of them [the three games] grant easy access to the research." (P1)

Table 6. Codes from "Suggestions to the games" theme

Code	# quot.	# part.	Quote
Suggesting the need for clearer explanation of the content within the *Data* game	25	13	"So that it doesn't feel so random [answering the questions from *Data*], where we have to just guess things, because you don't really have… you know? You don't have much prior knowledge when you start" (P6)
Suggesting the need for clearer explanation of the content within the *Categories* game	24	14	"I found the third game [*Categories*] confusing, I didn't understand what it was about, only that I had to link what I thought was right" (P13)
Suggesting changes based on existing games	12	4	"So if there were some mechanic, for example, similar to games like *Termo* or even traditional *Word Searches* you find in magazines — where you have a clue like 'a person who does something,' and then a set number of letters to figure it out — I think that would help the game's mechanics a lot. It would make things easier and, on top of that, more fun to try" (P20)
Suggesting the need for clearer explanation of the content within the games	11	7	"I think there should have some context of what exactly is the subject of the games" (P16)
Suggesting more keywords in the *Article* game	10	5	"In the first game [*Article*], I think I'd have revealed more words in the abstract text, words that weren't in the title" (P9)
Suggesting changes in the UI	8	6	"I think the game needs to be more visually appealing" (P7)
Suggesting improvements to the presentation of the games	7	6	"I think that kind of visual feedback… maybe adding some visual feedback to reward the player. Some confetti when you get it right, you know? I think *Duolingo* is a master at that. I find it very interesting." (P3)
Suggesting the need for clearer explanation of the content within the *Article* game	7	5	"Because it's very hard to guess [the words] with so little context [on the subject]" (P15)

quick and replayable games.

Although the games format was simple and praised, the *Data* and *Categories* games were criticized for being too simple. Both of these games were usually mentioned together by the participants, as they provoked similar feelings for them. Both were short experiences that made players frustrated when choosing wrong options, as they lacked context on the scientific topic shared through them, resulting in games that could feel like exams or tests.

As for the *Article* game, it had the opposite problem. The game was too difficult, long, and presented players with a lot of elements at once. *Article* also received complaints about a lack of context on the presented scientific subject, which could be an element that elevated the difficulty of the game.

This lack of contextualization on the scientific content shared is a commonly found sentiment with the games in the themes **Suggestions to the games** and **Negative perception**. A lot of codes relate to this problem indirectly, for example, the **Stating that they did not respond with confidence**, **Feeling frustration with the Categories game**, and **Negative feelings about making mistakes in games** codes involve a player's frustration in not being provided the information with which to answer the questions. From this sentiment, it is possible to define two recommendations: providing theme contextualization and a fair challenge, giving the necessary tools for the player to get involved with the challenge.

Another problem in the games was their lack of presentation. In this context, presentation means the visual and auditory stimuli during the experience of playing a digital game. This could involve the game aesthetic, user interface menus and elements, game feedback, among other elements of an game. The three games seemed too simple and sober for some participants, lacking the ludic elements of a game. Some players also felt the need of a better explanation or tutorial to the games, to better understand their goal and what they were supposed to do.

Table 7. Codes from "Successful Design" theme

Code	# quot.	# part.	Quote
Finding games intuitive	1	1	"I found it quite intuitive because of this aspect [viewing the article at the end of the game]." (P5)
Claiming to want to replay the games	1	1	"Like, maybe wanting to play again, maybe wanting to, like, do it, you know, like, ah, it didn't all work out this time, but I wanted to try again, you know? I got that urge" (P2)

Even with negative remarks, it is possible to see that the games divided opinions. The three games also received praise, with each of the 20 participants stating different favorites. Although the *Data* and *Categories* games were commonly associated with each other, both were on opposite ends in terms of acceptance and ability to engage with the scientific content. *Data* was the game with the most participants stating they had fun and engaged with the scientific content, while *Categories* had the least, with 10 of the 20 participants expressing they did not enjoy it. *Article* had a similar reception to *Data*, with participants enjoying the experience and feeling engaged with the scientific content shared through the game. A common sentiment about participants is that *Article* was the game that best explored the scientific content in a new and original way. This was observed to happen for a few reasons: it is the game that grants the most context of the research for the players; it provides a fun challenge, although too much of a challenge; and through that challenge, invites the player to think deeper on the subject. A big success of the games is that, even during the interviews, some participants expressed a desire to play the games again with other research and accessed the full papers shared to read them later. This desire is evidence of individuals engaging with the game and its scientific content. From these results we defined two more recommendations: providing different formats of games to share different research may prove efficient in engaging a larger audience; and the games which engaged players the most were the ones that better promoted their curiosity and interest in the scientific content being presented.

6 Recommendations

Throughout this research, it was possible to point five desirable elements of customizable games for scientific dissemination (also seen in Figure 12):

- **Theme contextualization:** The lack of contextualization of the research in the minigames reflected in a negative experience for the players. More context on what the research is about may promote not just fun but also interest in the subject.
- **Fair challenge:** A balanced level of challenge is essential to maintain players engagement with both the game and the scientific content. This was reflected in participants frustration when providing incorrect answers and perceiving the experience as similar to an exam or test.
- **Quick and simple:** Participants expressed positive feedback regarding the game format. Simple and brief minigames were perceived as easier to learn and more inviting to be revisited in the future with different subjects.
- **Different formats of games:** As seen in the collected results, although some minigames were more successful in their goals than others, different participants expressed different opinions on favorites and in which interested them the most in the shared content. This reflects a successful decision in providing three different formats of minigames, as they may appeal to different players and reach a larger audience.
- **Promotes critical thinking on the subject:** Participants showed the greatest interest in minigames that encouraged reflection on the scientific content being presented. A game that promotes critical thinking on the subject can not only fulfill the objective of disseminating scientific knowledge but also provide an engaging and challenging experience.

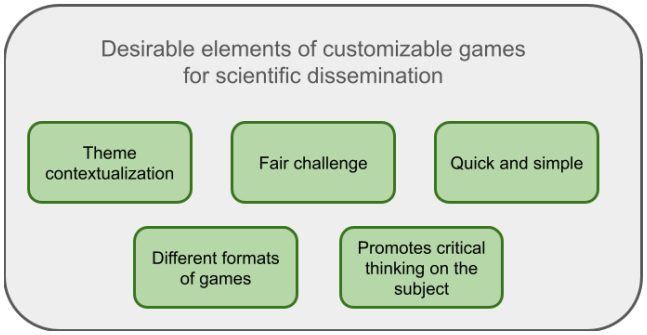

Figure 12. Desirable elements of customizable games for scientific research found in this study

7 Conclusions

This study evaluated through interviews and thematic analysis the efficacy of three customizable minigames as a means of scientific dissemination. The evaluation aimed to understand the games from the perspective of the players, how they would react to the three games, and the research shared through them. The desirable elements in customizable games with the purpose of scientific research found in this study can be seen in Figure 12.

Through the analysis of the gathered results, it is possible to infer relevant conclusions. The results show that the emulated format of popular daily games was well accepted by the participants and proved potential to promote interest both in the games and in the scientific content. It is also noticeable that short and replayable games have a positive influence on the players' engagement. This reinforces the utility of a tool that can allow researchers from different fields to share their research results through games, to maybe reach a different audience.

The interviews provided evidence of interest on the part of the players in games like these, which do not require a large commitment of time but can also be fun and informative. It is also possible to learn from these games mistakes, as it was observed, they could be more successful with more contextualization of the research for the player, so they can have more information on which to reflect when presented with the game challenge. This would make the experience fairer, engaging,

and less frustrating for the players. Another issue reported by participants was the lack of a playful presentation. The games were perceived as overly serious and formal, conveying the feeling of an exam or test. New versions of these games could improve in this aspect, which may enhance the engagement of the players with the games and their content.

Results also showed that the players did engage with the scientific content through the shared games, although to different extents. *Article* and *Data* were the favorites and the most successful in engaging the participants with the shared research. These are also the games that provide the most context and require more critical thought to be completed. Even so, some participants identified *Categories* as their favorite game, indicating that offering multiple game options rather than relying on a single larger format was an appropriate choice for the purpose of reaching a wider audience.

In conclusion, this work demonstrates that tools that facilitate the creation of simple games have the potential to broaden the reach of scientific dissemination by lowering the technical barriers that researchers would have to go through to develop their own serious games. Despite the study's limitations, the findings provide consistent initial evidence that this approach can stimulate interest, curiosity, and in some cases, the active pursuit of scientific knowledge.

It is important to note that this study was carried out with 20 individuals from the same course, and people with different backgrounds could possibly have different opinions and experiences. This specific participant profile may have influenced the results, as they are students enrolled in an undergraduate program and are already familiar with the process of game development. Individuals in other age groups and with different backgrounds may yield different results. Another limitation of this work is that each of the games was presented sharing a different research, while *Article* and *Data* shared content related to serious games, the participants' field of interest, the game *Categories* shared research on public administration, a very different topic. The different topics shared may have impacted the answers and experiences of the participants.

Future work may involve the replication of this work with a larger number of participants of different backgrounds and profiles, such as high school students or adult members of the general public. Another suggestion is to apply the recommendations found in this research to the developed minigames and conduct a larger test, including the viewpoint of the researchers who would use these tools.

Declarations

Acknowledgements

We thank the Pontifical Catholic University of Minas Gerais (PUC Minas), Juan Vitor Saar Silvério and all students who took part in the recorded interviews for their interest and support.

Funding

We thank the Fundação de Amparo à Pesquisa de Minas Gerais (FAPEMIG) for the scholarship and financial support (APQ-5058-23 - Sustentabilidade no cenário pós-pandêmico: desafios e contribuições) and the National Council for Scientific and Technological Development (CNPq) for the financial support and scholarship (Grant 409249/2023-8).

Authors' Contributions

The authors' contributions to the paper were as follows. Daniel Duarte Ckagnazaroff carried out software development, writing, research, methodology application, data collection, and analysis, supervised by Lucila Ishitani. Milena Soares Barreira and Raphael Ramos Dias Costa contributed with methodology application, data collection, analysis, and validation Lucila Ishitani also edited, corrected, and offered suggestions to improve this document.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The codes and quotations found during the thematic analysis of the conducted interviews: `https://sgapucminasbr-my.sharepoint.com/personal/1199234_sga_pucminas_br/_layouts/15/guestaccess.aspx?share=IQBO1gT7-QGbTYE1Fmx0JOUJAbVge-9QNFQ0IlieVOIiWPQ&rtime=FNKRTGaW3kg`

The developed editor that allowed the creation of the three minigames can be accessed through the following link: `https://eumsmo.github.io/puc-ic/Editor/`

The three minigames provided to the participants can be played in the following links:

- *Paper*: `https://eumsmo.github.io/puc-ic/Build/?drive=1wciOUsUK3trl75eW8S-ZOBcoBrRH7woN`
- *Data*: `https://eumsmo.github.io/puc-ic/Dados/Build/?drive=1QYK_DqHHU7sHRIJuUDgTaxgG122NZVcQ`
- *Categories*: `https://eumsmo.github.io/puc-ic/Associacao/Build/?drive=1NQMjOu1d3nzwoy95pWkQ4C2OLl1rYpMG`

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