Development of a customizable Serious Game for scientific dissemination: An approach based on Action Research

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Abstract. Introduction*: Games have been used for purposes beyond entertainment with great success. One of these purposes is Scientific Dissemination, utilizing a game's ludic aspects to engage the general public with scientific research.* ***Objective:*** *This study aims to identify desirable characteristics of customizable Serious Games for purposes of Scientific Dissemination through the development of two minigames and their editors.* ***Methodology or Steps****: The Action Research qualitative research methodology was employed due to its "learning by doing" approach, which enables the team to gain a deeper understanding of the target audience's needs.* ***Results:*** *We developed two customizable games and their editors through two Action Research cycles. This experience enabled the team to identify four desirable characteristics for customizable games used in Scientific Dissemination.*
Keywords *Serious Game, Action Research, Scientific Dissemination, Game, Heuristic Evaluation.*

1. Introduction

Serious Games (SG) refer to games that utilize their ludic elements for purposes beyond entertainment, such as educational content or to achieve a specific goal [Ahrens 2015, Becker 2021]. They have been utilized since the latter half of the 20th century as a fun way to engage with serious and educational topics [Djaouti et al. 2011, Ravyse et al. 2017]. These types of games have been applied in various fields, such as children's education [Yanti et al. 2019] and healthcare [Damaševičius et al. 2023].

Among these various applications, SGs have been utilized to support the development and dissemination of scientific research [Signa et al. 2022, Kuo e Chuang 2016]. Scientific research findings can be presented to the general public in a more engaging manner through the interactivity of a game.

The main limitation of this approach is the significant time and expertise required to develop an SG. A key challenge is to understand how to create simple, customizable minigames that are easy for the general public to understand, and a tool that allows

researchers, who may not be tech-savvy, to adapt these minigames to different types and subjects of scientific research.

Thus, the goal of this study is to identify characteristics of a customizable SG through the development of customizable minigames and their editors for use in the context of scientific dissemination. These games were designed, following brainstorming sessions, to enable researchers from different fields to share their research through SGs that can be understood by players who may or may not play games casually.

In this project, we adopted the Action Research methodology to understand the needs of stakeholders and develop the minigames. Action Research is a cyclical qualitative research approach that integrates problem-solving with stakeholder participation [Engel 2000, Davison et al. 2004]. The first research cycle focused on developing the initial minigame and its editor, while the subsequent cycle aimed not only to address the shortcomings of the previous minigame but also to develop a new minigame that could overcome its limitations.

Two minigames and their editors were completed, both simple to understand but with different purposes, allowing for various approaches that may suit a range of research. We identified the needs of both researchers and players as guidelines for the third cycle of Action Research and future efforts in developing customizable games for scientific dissemination.

This paper is organized into four additional sections. Section 2 elucidates the background and necessary knowledge for a comprehensive understanding of this study. Section 3 explains the Action Research methodology and its application in this research. Section 4 presents the analysis of the data accumulated from the Action Research cycles and evaluates the effectiveness of the two developed minigames. Section 5 provides the research conclusions and suggestions for future work.

2. Background

This section presents the fundamental concepts for understanding this article. It is organized into three subsections: Customizable Games, which refer to games that can be adapted to various scenarios; Scientific Dissemination, the process of democratizing knowledge by presenting scientific results and concepts to the general public; and Action Research, a qualitative research methodology based on learning by doing.

2.1. Customizable Games

A common limitation of SGs, as noted in the literature, is their specificity and strong ties to their primary theme and purpose. While most of these games have been shown to be effective in achieving their objectives [Backlund e Hendrix 2013], the process of developing a game is very time-consuming and typically requires prior knowledge of programming or game design concepts. However, a customizable game would allow a researcher, who may not be familiar with the necessary technology, to create their SG according to their subject or research [Nogueira et al. 2013].

Customizable games can be adapted to various scenarios and offer different levels of customization. For example, an SG designed for disaster emergency training may allow modifications to the scenario or intensity [Feng et al. 2020], while an educational

game may enable teachers to adjust text or images [Bontchev 2015]. The degree of customization in an SG depends on its purpose, target audience, and scope.

2.2. Scientific Dissemination

Scientific dissemination is the process of sharing scientific knowledge and research findings with broader audiences. Its primary purpose is to educate the general public about their context and help them make informed decisions [Lordêlo e Porto 2012, Albagli 1996].

The methods of scientific dissemination vary depending on the target audience, the resources available to the researchers, and publication goals. There are several ways to achieve this, some examples include media such as videos [Bourne e Chalupa 2008], social media [Velazquez-Solis et al. 2022], and games [Kuo e Chuang 2016]; traditional scientific publications [Fawcett et al. 2020]; and practices like citizen science [Miller et al. 2023].

2.3. Action Research

Action Research is a qualitative methodology that integrates academic research with empirical action. It is a process of learning by doing, enhancing researchers' comprehension and knowledge while bridging the gap between theory and practice [Engel 2000].

Action Research is typically applied in circumstances involving real-world problems, as it focuses on solving practical issues; it is also utilized as a preliminary method of research, especially in ambiguous situations, which can be challenging to define a precise research question [O'Brien 1998]. There are various approaches to this methodology, depending on goals, circumstances, and collaboration methods, among other factors [Tripp 2005, Orosz et al. 2023].

The Action Research method applied in this research is referred to as Canonical Action Research and follows a cyclical process consisting of five steps [Davison et al. 2004]:

1. **Diagnosing –** Identifying and defining the problem.
2. **Action Planning –** Analyzing data and developing a plan to address the defined problem.
3. **Taking Action –** Executing the plan.
4. **Evaluating –** Monitoring stakeholders' reactions, and assessing the effects of the plan's execution based on collected data.
5. **Specifying Learning –** Establishing the results and refining the process before repeating the cycle.

3. Related Works

The related works selected for this research aim to present serious games that are customizable or utilized in the context of scientific dissemination. They either search for an easier way to allow researchers and teachers to utilize serious games, or promote the general public engagement with scientific research.

The online portal for educational games *Pingo* was developed in 2013. In addition to offering various minigames designed for children, it provided teachers with an editor

to create customized versions of the games as a teaching tool for their respective subjects [Nogueira et al. 2013]. Although it shares similar goals with this article, *Pingo* focuses on educating young children rather than disseminating scientific information to the general public.

Bontchev (2015) developed a game around a customizable 3D maze. Through an editor, a teacher could easily change images and text on the maze walls according to their respective lecture subjects. Upon exploring the maze, players develop their spatial and visual thinking, improve their motor skills, and assimilate new concepts, ideas, and theories. Although the research presents a customizable game, the project doesn't approach the goal of scientific dissemination, and is limited by the maze format.

The platform PUOPA was developed for the National Pingtung University of Science and Technology (NPUST) in Taiwan as an initiative to utilize gamification for scientific dissemination. It features various minigames, along with elements such as leaderboards and rewards [Kuo e Chuang 2016]. However, the platform is limited to NPUST and does not include tools for creating customized minigames.

In 2022, the game *BubbleMumble* was developed for scientific dissemination. Its purpose was to present the results of scientific research to students aged 13 to 16 in an engaging and accessible way, encouraging their interaction with both the game and the knowledge it conveys [Signa et al. 2022]. A limitation of this approach is the lack of customization in the game's content, as it is restricted to a specific research.

Therefore, there is growing interest in both the use of games as a means of scientific dissemination and in customizable games that enable researchers and educators to create such games more easily.

4. Methods

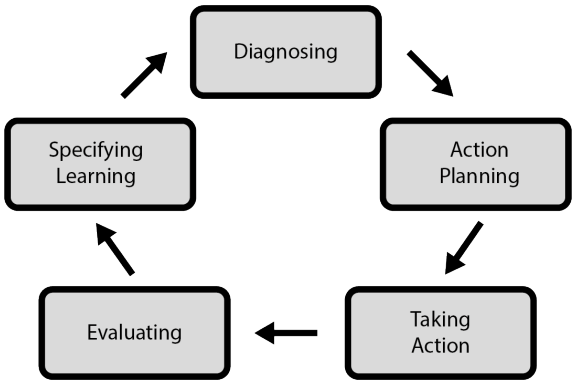


Figura 1. Action Research Cycle

Action Research is the research methodology chosen to be applied in the development of two customizable minigames with the purpose of scientific dissemination. It follows a learning-by-doing approach to scientific research, engaging stakeholders in problem-solving. The cycle of Action Research chosen for this research consists of five steps, as seen in Figure 1.

In this work, we conducted two cycles for the development of the minigames and their editor, one cycle for each minigame and its editor, as this project aims to create

a variety of minigames that suit different research needs. We analyzed the first cycle feedback to address the problems identified in the initial minigame and to guide the development of the second, which would fulfill a different purpose and compensate for the limitations of the first.

Diagnosing: The first step involves identifying the problem. In this research, we did this by collaborating with other researchers in the broader science dissemination research initiative in which this project is involved. The problem, as defined in this paper, is to overcome the limitations of SGs as a means of scientific dissemination by facilitating the development process for non-tech-savvy researchers and presenting a game that is easy to understand for the general public, who may not be familiar with these technologies.

Action Planning: Once the problem is defined, the next step is Action Planning. The key question to address is how to facilitate the development of SGs by researchers, the project's stakeholders. This process involved a systematic review of the literature and four weekly brainstorming sessions with the researchers of this project.

Taking Action: The development of the first game and its editor took place during the third step. After defining the initial minigame based on the collected information, the development began. The goal of this step was to produce a first release build for the stakeholders.

Evaluation: Upon completing the first minigame, the Evaluation step began. Each research cycle tackled it differently. In the first cycle, testing of the first game and its editor happened with the immediate development team, involving researchers and graduate students. On the second cycle, we presented the games and their editor to researchers from the broader research initiative, who participated in a heuristic evaluation. We collected their feedback for analysis. Once we analyzed the data collected, identifying both positive and improvement aspects, we could understand how to enhance the project. We considered the stakeholders' experience and suggestions for the next cycle.

Specifying Learning: The final step involves defining the main issues and limitations of the first attempt so they can be addressed in the next cycle. The second cycle, starting from the first step (Diagnosing), focuses on implementing the necessary fixes and updates to the first minigame and its editor, as well as developing a second minigame designed to overcome the limitations of the first.

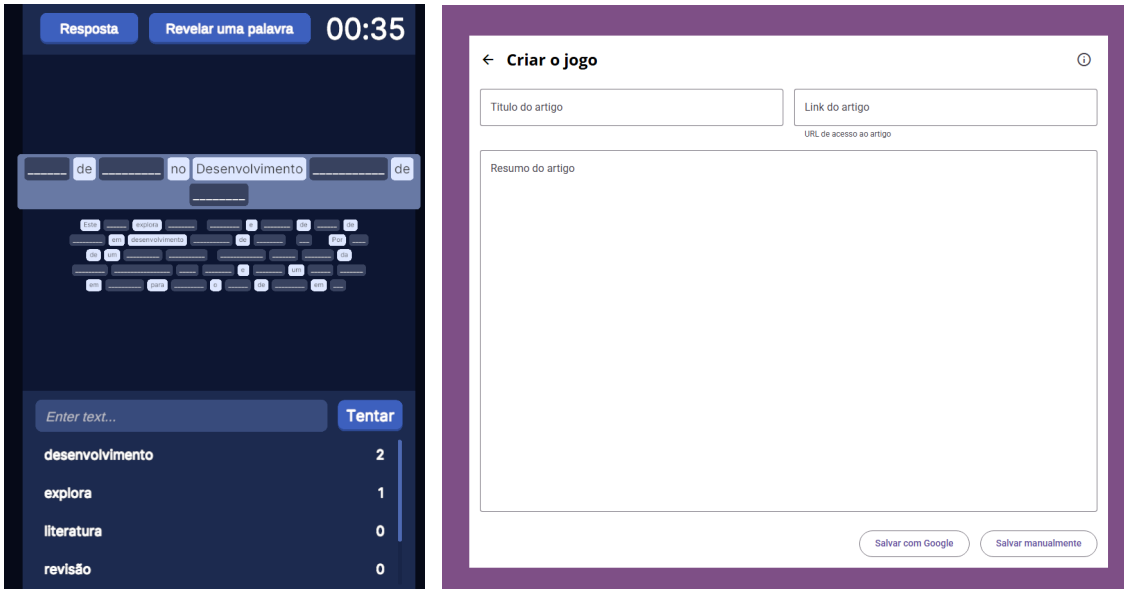
5. Results

This section presents the results obtained throughout each step of the Action Research process. It is divided into three subsections. Subsections 1 and 2 detail each research cycle. Subsection 3 defines the desirable characteristics for a customizable game for scientific dissemination.

5.1. First Cycle

The primary objective of the first cycle was to understand the needs of both researchers and the general public regarding a customizable serious game for scientific dissemination.

After four brainstorming sessions involving the immediate research team and discussions with researchers involved in the broader research initiative this project takes part in, the development of a customizable minigame and its editor began. Both of them were developed using the Unity engine and C#.



(a) Article Minigame **(b)** Article Game Editor

Figura 2. First game

The Article Game, presented in Figure 2a, was based on casual daily minigames like the New York Times Wordle[1] and "artigo.app"[2] because of their simplicity and success in engaging the general public. We chose this kind of minigame in an attempt to make the game easier to understand for a general audience who may not be familiar with either complex games or scientific research. We utilized a similar approach in the games editor (Figure 2b), which we designed to mimic the creation of a "Google Form", a tool commonly used by teachers and researchers. These decisions are a result of the discussions among the researchers on the development team.

In the game, the Player must uncover the article's title by guessing words that appear in both the title and the abstract. As more words are revealed, the article's context becomes easier to understand. The game editor allows the researcher to customize the title and abstract presented in the game to fit their specific research and results. The researcher can also link their paper to be read after the game concludes.

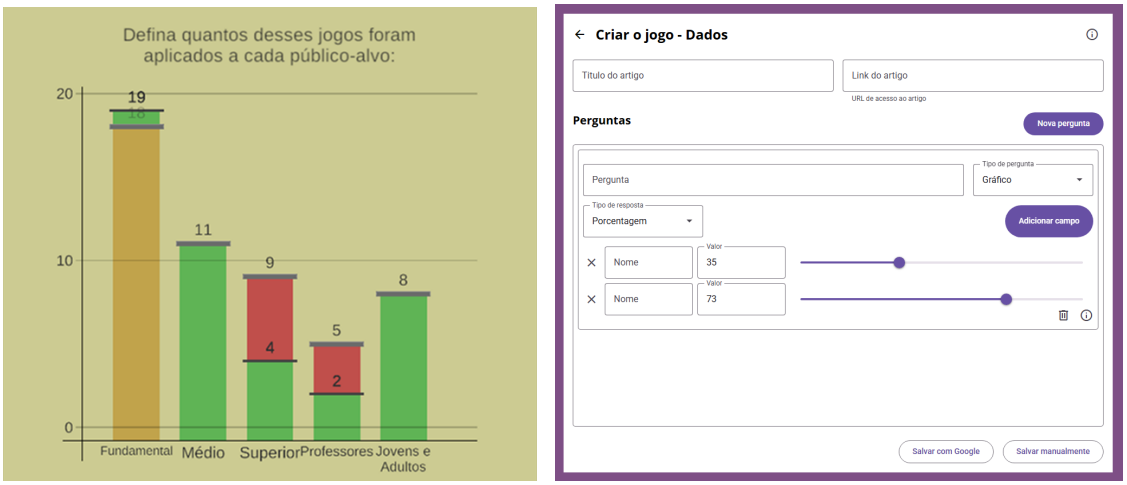
We tested both the Article game and its editor, evaluating them with researchers directly involved in this project. The game was deemed too hard, raising concerns about its ability to engage the general public and grow interest in the displayed academic research. Players found it challenging to uncover all the words and complete the game, resulting in a frustrating experience. The team found the editor successful in accomplishing its goal. The game format limitations were also considered, prompting

[1]https://www.nytimes.com/games/wordle/index.html
[2]https://artigo.app/

the development of a second minigame to address different research and needs that the Article game format couldn't cover.

5.2. Second Cycle

The second cycle involves addressing the main problems identified in the Article game through updates and initiating the development of the second minigame, the Data Game, along with its editor. We developed both games with the same goals: to be easy to understand and customize, while engaging the Player in reflecting on the displayed research content. While the Article game focuses on text, the Data game aims to present a more visual experience, which may require less effort from the Player, but can also be a way to engage with the research subject.



(a) Data Minigame **(b)** Data Game Editor

Figura 3. Second game

The Data Game, seen in Figure 3a, is played like a quiz with three different types of questions: binary "yes" or "no" questions; prompts to guess the different values in a customized column graph; and a prompt to guess the percentage of a single category. The goal of this game is to engage the player in thinking about interesting research results, which may generate a greater curiosity about the subject.

The Data Game Editor, Figure 3b, was designed to mimic the creation of a "Google Form" in a similar manner to the Article Game Editor. This decision was made following the success of this approach in the first cycle. As the Data Game has three different types of questions, this Editor is more complex than the one for the Article Game, allowing the modeling of customizable column graphs and the creation of more questions in the same game.

In this cycle, we updated the Article Game to address the issues identified in the previous iteration. The game was initially considered too hard, so two new buttons were added in an attempt to fix the problem: a "Reveal Word" button, which reveals a random word from the paper's abstract, and an "Answer" button, which allows a player who has given up to access the full paper without needing to guess the entire title.

In the second cycle, the evaluation involved another group of participants from the project in which this work is included. They were not involved in the previous conversations or the construction of the two minigames. The evaluators were four undergraduate students and a researcher in the field of human-computer interaction. For the evaluation of the game editor and minigames, they conducted a heuristic evaluation using the Nielsen Heuristics [3]. This method is quick, easy to apply, and identifies interface usability problems, indicating where they occur, their severity, and providing suggestions for improvement.

The evaluators followed a script that involved creating two games ("Article" and "Data") based on a scientific article, using the game editors, and then playing them. After the individual assessments, all evaluators met in person and created a unified report; cases of disagreement were resolved by consensus during the meeting.

The main problems are related to the visibility of the system status, the match between the system and the real world, and user control and freedom, which can make it difficult for less experienced users to use and can lead them to give up. These problems are mainly related to the games. The game editors, on the other hand, had fewer problems, indicating better usability. The biggest problem is saving games, which remains a challenge due to the numerous steps required.

The game editor received positive reviews, and where it might be difficult for users, the developers have added help points to support them. The minigames were easy to manipulate. Only the feedback and documentation were identified as areas for improvement by the evaluation. As a final result, the software (game editor and games) was rated as having good usability but needs improvement for Cycle 3[4].

5.3. Characteristics of a Customizable Game for Scientific Dissemination

After two Action Research cycles, the development of two customizable minigames and their editors, and analyzing what went right and what went wrong, we can present the desirable characteristics of a customizable game for scientific dissemination found in our research:

- **Simplicity:** Both the game and its editor should be as simple as possible to use or play. This characteristic reflects the game's target audience, which, in the case of scientific dissemination, is usually the general public, who may or may not be familiar with these technologies.
- **Engagement:** The game should be fun and offer a challenge, not too hard, but enough to engage the player with the customized content. Nice visuals and player feedback are also effective ways to enhance player engagement.
- **Options:** Teachers and researchers should be able to apply their research to the customizable games in different ways with minimal effort.
- **Access:** The game and editor should be accessible through familiar means, such as web browsers and phones, and be optimized to allow users who may have older or weaker hardware.

[3] https://www.nngroup.com/articles/ten-usability-heuristics/

[4] The report is available at:
https://docs.google.com/document/d/1RZuHKrXXl4GlOWgkOSncPaKzuAMenuQo0o9OB26xtEc/edit?usp=sharing

- **Timesaving:** Although the length of an SG could vary depending on context, we found that players might be more inclined to try these games if they seem short or not too time-consuming.

These characteristics should work as goals to be met for the development of a customizable game for scientific dissemination. They aim to facilitate the use of the tools by researchers, while providing them with more options and reaching the general public by making it easier to access and play, without requiring significant effort.

6. Conclusions

During two cycles of Action Research, we developed two minigames and their editors, the Article game and the Data game. They were both evaluated, and feedback will be considered in a third cycle. Although these games were successful in achieving their goal of being customizable SG for scientific dissemination, a heuristic evaluation revealed usability problems that need to be addressed to fulfill the desirable characteristics identified in this study fully.

The desirable characteristics of a customizable game for scientific dissemination defined in this study are: Simplicity, Engagement, Options, Access, and Timesaving. These characteristics mean that the game should be simple to understand and customize, fulfill the needs of the researcher creating the game, engage the player with the research in a fun way, and be accessible to the largest number of users.

Although they are more complex than the games, the editors were better evaluated. Both were easy to use, and in more challenging steps, such as the questions in the Data game, sufficient support and instructions were provided by the developers. Still, they can be updated to streamline the user experience.

The Action Research methodology enabled the team to learn by doing, to understand the needs of the target audience better, and to respond to those needs effectively. It also provided an opportunity to learn from previous mistakes, make improvements, and further refine the understanding of those needs.

Future work could involve testing the customizable Serious Games as a means of scientific dissemination with a broader audience, particularly individuals outside the academic community. This evaluation could employ different qualitative research methods to understand better the efficacy of this type of game in research dissemination.

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Referências

Ahrens, D. (2015). Serious games – a new perspective on workbased learning. *Procedia - Social and Behavioral Sciences*, 204:277–281.

Albagli, S. (1996). Divulgação científica: informação científica para cidadania. *Ciência da informação*, 25(3).

Backlund, P. e Hendrix, M. (2013). Educational games - are they worth the effort? a literature survey of the effectiveness of serious games. In *2013 5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES)*, pages 1–8.

Becker, K. (2021). What's the difference between gamification, serious games, educational games, and game-based learning. *Academia Letters*, 209(2):1–4.

Bontchev, B. (2015). Customizable 3d video games as educational software. In *EDULEARN15 Proceedings*, 7th International Conference on Education and New Learning Technologies, pages 6943–6950. IATED.

Bourne, P. E. e Chalupa, L. M. (2008). A new approach to scientific dissemination. *Materials Today*, 11(6):48.

Damaševičius, R., Maskeliūnas, R., e Blažauskas, T. (2023). Serious games and gamification in healthcare: a meta-review. *Information*, 14(2):105.

Davison, R., Martinsons, M. G., e Kock, N. (2004). Principles of canonical action research. *Information Systems Journal*, 14(1):65–86.

Djaouti, D., Alvarez, J., Jessel, J.-P., e Rampnoux, O. (2011). Origins of serious games. *Serious games and edutainment applications*, pages 25–43.

Engel, G. I. (2000). Pesquisa-ação. *Educar em revista*, pages 181–191.

Fawcett, W., Charlesworth, M., Cook, T., e Klein, A. (2020). Education and scientific dissemination during the covid-19 pandemic. *Anaesthesia*, 76(3):301.

Feng, Z., González, V. A., Mutch, C., Amor, R., Rahouti, A., Baghouz, A., Li, N., e Cabrera-Guerrero, G. (2020). Towards a customizable immersive virtual reality serious game for earthquake emergency training. *Advanced Engineering Informatics*, 46:101134.

Kuo, M.-S. e Chuang, T.-Y. (2016). How gamification motivates visits and engagement for online academic dissemination – an empirical study. *Computers in Human Behavior*, 55:16–27.

Lordêlo, F. S. e Porto, C. d. M. (2012). Divulgação científica e cultura científica: Conceito e aplicabilidade. *Revista Ciência em Extensão*, 8(1):18–34.

Miller, J. A., Buse, K., Dhaliwal, R. S., Siegel, J., Cooper, S., e Milburn, C. (2023). Wrapped in story: The affordances of narrative for citizen science games. In *Proceedings of the 18th International Conference on the Foundations of Digital Games*, FDG '23, New York, NY, USA. Association for Computing Machinery.

Nogueira, D. N., Chaimowicz, L., e Prates, R. O. (2013). Pingo-an online portal for educational games with customizable content. *Proceedings do XII Simpósio Brasileiro de Jogos e Entretenimento Digital. São Paulo*, pages 80–89.

Orosz, A., Recino, U., e Ochoa, M. (2023). Demo lessons and peer observation to enhance student teachers' competencies and exit profiles. *International Journal of Learning, Teaching and Educational Research*, 22:638–658.

O'Brien, R. (1998). An overview of the methodological approach of action research.

Ravyse, W. S., Seugnet Blignaut, A., Leendertz, V., e Woolner, A. (2017). Success factors for serious games to enhance learning: a systematic review. *Virtual Reality*, 21:31–58.

Signa, A., Gentile, M., Picciotto, S., Cusimano, A., e Perna, S. (2022). Bubblemumble: A serious game for the dissemination of scientific results in secondary schools. In *CSEDU (2)*, pages 467–474.

Tripp, D. (2005). Action research: a methodological introduction. *Educacao e pesquisa*, 31:443–466.

Velazquez-Solis, P. E., Flores-Rios, B. L., Angélica, A.-V. M., Ibarra-Esquer, J. E., Fernando, G.-N. F., e Antonio, A. V. R. (2022). Analysis of scientific dissemination posts on facebook from a social media approach. In *2022 17th Iberian Conference on Information Systems and Technologies (CISTI)*, pages 1–6.

Yanti, P. P., Rosmansyah, Y., e Dabarsyah, B. (2019). Serious games for children: A systematic literature review. In *2019 International Conference on Informatics, Multimedia, Cyber and Information System (ICIMCIS)*, pages 79–84.