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ReciCaos: A Cooperative Digital Game for Studying Solid Waste Recycling

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Abstract: This article presents the development of an educational digital game inspired by the game *Overcooked*, designed to teach and raise awareness among its players about the selective collection of solid waste in a fun, engaging, and cooperative way for players of all ages. The game combines elements of challenge and teamwork to engage players while demonstrating the importance of proper waste management through interactive scenarios. A case study involving 31 volunteer participants used an adapted version of the MEEGA+ model to evaluate the game. The results indicated that blending entertainment with education can effectively promote environmental awareness and encourage eco-friendly behavior among young and adult audiences.

Keywords: educational games; environmental awareness; recycling education; solid waste management, interactive learning.

ReciCaos: Um Jogo Digital Cooperativo para Estudo de Reciclagem de Resíduos Sólidos

Resumo: Este artigo apresenta o desenvolvimento de um jogo digital educativo, inspirado no jogo *Overcooked*, com o objetivo de ensinar e conscientizar seus jogadores sobre a coleta seletiva de resíduos sólidos, de forma lúdica, atrativa e cooperativa para todos os públicos. O jogo incorpora elementos de desafio e cooperação para engajar os jogadores, ao mesmo tempo que promove a experimentação de situações sobre a importância da gestão adequada de resíduos. O estudo de caso conduzido nesta pesquisa utilizou uma adaptação do modelo MEEGA+ aplicado a 31 participantes voluntários. Os resultados mostraram que a combinação de entretenimento e educação pode ser uma ferramenta eficaz para promover a conscientização ambiental e incentivar comportamentos ecológicos em um público jovem/adulto.

Palavras-chave: jogos educativos; educação ambiental; reciclagem; resíduos sólidos, aprendizado interativo.

1. INTRODUCTION

Growing concern for the environment and the need for sustainable practices make it essential to educate society about the importance of selective solid waste collection. In Brazil, where urban waste production has increased significantly, environmental awareness and education are crucial to reducing environmental impact and promoting sustainability (SANTIAGO, 2024). In this context, educational games are a powerful tool for engaging and teaching individuals about ecological practices, using interactive and playful approaches. Educational games combine entertainment with pedagogical

objectives, providing an engaging and dynamic learning experience (DE VASCONCELLOS *et al*., 2017; CARVALHO *et al*., 2023). They can transform abstract concepts into practical and interactive tasks, facilitating the assimilation of knowledge and the development of skills (PRENSKY, 2001).

Inspired by the popular game *Overcooked* (GHOST TOWN GAMES, 2016), this paper proposes developing an educational game centered on a selective solid waste collection, simulating a recycling cooperative. *Overcooked* is known for its cooperative dynamics and focus on managing tasks in a chaotic kitchen environment. By combining the elements of challenge and cooperation that are characteristic of this game with environmental educational content, this work aims to develop and to analyze whether an educational game can raise awareness and educate about responsible environmental practices besides providing a playful and fun experience for audiences of all ages.

A study was conducted with 31 general public participants for the game's initial evaluation. A questionnaire adapted from the MEEGA+ model – Model for the Evaluation of Educational Games – (PETRI *et al*., 2019) was applied to validate the participants' impressions about the game and to determine whether it could be adopted as an educational tool.

This paper is structured as follows: Section 2 discusses the concept of selective waste collection and related work. Section 3 explains the research development and validation process, and the game design of the proposed game. Section 4 presents and discusses the study results, and Section 5 reports the conclusions.

2. BACKGROUND

Selective collection is a process of separating recyclable waste with similar characteristics, which is carried out by its generators. These generators may be individuals, companies, or institutions (MINISTÉRIO DO MEIO AMBIENTE, 2016). According to Dias (2011), selective collection is essential for sustainable solid waste management, reducing the amount of waste sent to landfills and promoting recycling. Data provided by the Sistema Nacional de Informações sobre a Gestão dos Resíduos Sólidos – SINIR (2021) shows that, in 2019, 54 tons of waste from domestic activities in urban homes or public road cleaning had a designed destination. Still, only 3.55% of this amount was recycled or composted.

The Política Nacional de Resíduos Sólidos (PNRS – Brazilian National Policy for Solid Waste), instituted in 2010 by Law No. 12.305/10, brought the issue to the political agenda and raised society's awareness, as opposed to the previous stance of simply removing solid waste from population agglomerations. The PNRS brought an innovative and complex framework with challenging targets for a current negligence scenario. However, the results are still uncertain a decade after the law was passed, and integrated solid waste management has dragged (SANTIAGO *et al*., 2023).

In environmental education, games are powerful tools for raising awareness and enlightening about the importance of sustainability and ecological conservation (SKALEE *et al*., 2017). Famous games such as *SimCity* and *Minecraft Education Edition* allow players to explore concepts of sustainable urbanism and conservation practices in simulated environments. Another example is *Save the Ocean* (SOUZA *et al*., 2019), which addresses the issue of selective waste collection. Within the environments proposed by these games, students become responsible for decisions and consequences, positioning them as the protagonists of the problem being addressed.

2.1 Related Work

This subsection presents some of the literature works that explore how educational games can support the study or awareness of environmental issues. An exception is *Overcooked*, which inspired the core mechanics of the game *ReciCaos*, thus justifying its presentation in this subsection. The research by Kirchhof *et al*. (2023) aimed to develop a serious game for mobile devices called *Fazenda Sustentável* (*Sustainable Farm*) to help disseminate content related to environmental education and sustainable development. In the game, the player must take care of a farm in the most sustainable way possible. The game allows topics such as crop rotation, sustainable planting, the use of green inputs, pesticides, beekeeping, the preservation of springs and rivers, protected areas, soil and water use, grazing, and composting to be addressed in a playful and fun way regarding the theme of sustainable development and sustainability.

Save the Ocean (SOUZA *et al*., 2019) is a serious and competitive game for personal computers in which two players control mechanical sharks capable of collecting waste from the ocean. The players compete, and the one who collects the most waste wins. The game's main mechanics consists of rotating the colors of the selective collection so that only one type of solid waste is scored at a time. If the wrong kind of waste is collected, the player loses points. The educational objective is for the player to associate the colors of the selective collection and better understand the importance of disposing of solid waste correctly. A case study was carried out with 10 participants to evaluate the game. As a result, the participants became more aware of environmental issues after using the game. Before playing, 40% were unaware of the color system used in the garbage can, and 30% were totally familiar with the system. After playing, 90% of the players fully knew the colors used in recycling and selective collection. To increase students' motivation to learn concepts related to the prevention of natural disasters, the research by Tsai *et al*. (2020) targeted flooding as a problem, simulating concrete disaster experiences. In the game *Battle of Flooding Protection*, students play the role of a decision-maker in a city suffering from flood disasters. To avoid failure, the students considered various influential factors, such as time, money, and personal and public interest. The more balanced these factors are, the higher the score.

Overcooked (GHOST TOWN GAMES, 2016) is a cooperative simulation game with a culinary theme. It is widely known in the gaming industry, with versions for consoles and personal computers. In it, players must work in a coordinated way, preparing, cooking, and serving each order within a pre-established time. As time elapses, the queue of orders grows, and new obstacles and problems are presented to the players, gradually increasing the game complexity and creating a chaotic environment. Although this is not an academic work and does not fall under the classification of an educational game, it is necessary to mention this game since the *ReciCaos* game, developed in this study, had its visual design and mechanics inspired by it.

3. METHOD

The 3D digital game proposed in this research – *ReciCaos* – promotes environmental awareness as an educational tool, considering that issues of this nature affect the entire population. Another fundamental aspect is that the game should appeal to all ages. Thus, the simulation genre was chosen, inspired by the mechanics presented by the game *Overcooked*, characterized mainly by cooperation between players and the overload of problems to be solved. The game was named *ReciCaos* because it combines the terms "Recycling" and "Chaos," alluding to the educational subject covered in this

work and the purposeful disorder, in terms of the entertainment generated by the mechanics implemented in the game.

3.1 *ReciCaos* Game

The *ReciCaos* game was developed using the Unity graphics engine, one of the most popular environments for game development (COWAN; KAPRALOS, 2017). The version of the game generated in this research is for personal computers. The game can be accessed at the following link: https://gamejolt.com/games/recicaos/889311. *ReciCaos* consists of four phases, with a gradual increase in difficulty, and can be played by one or two players. Players aim to recycle as much solid waste as possible in the game and prevent it from being incinerated. Players must collect, store, and recycle the trash in their respective garbage cans, respecting the colors of recycling, i.e., selective collection.

The following basic mechanics were defined for the game: (1) players must carry out selective waste collection. For this, the waste provided by the game via the conveyor belt must be collected and stored in their respective garbage cans based on color; (2) for each type of waste, the garbage container can be filled with three units. After this, the trash container can be filled, and the players must empty it by taking the stored waste to a recycling machine. If the garbage can is not complete, the player will not be able to take these materials to the recycling machine; (3) the recycling machine will transform the waste (previously removed from the garbage can) into recycled material, which must be delivered to another conveyor belt, thus concluding the recycling process. Players will be rewarded with points for each recycled material delivered. If players fail to collect the waste, allowing the items to be incinerated, a penalty is applied with a loss of points. At the end of each level, if the players score positively, the next level is released. Figure 1 illustrates the basic mechanics described in steps 1, 2, and 3. For the scope of the project, four types of waste and their respective colors were used: paper (blue), metal (yellow), glass (green), and plastic (red). Organic waste (brown) was also used as a bonus.
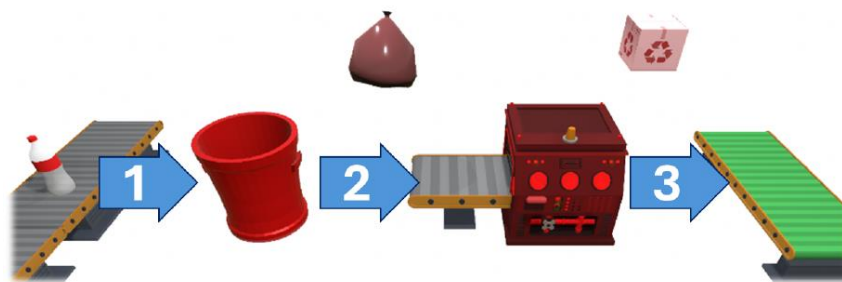

Figure 1. Basic mechanics of the ReciCaos game. Source: The authors.

Based on the approach suggested by Schell (2019), the game design of *Overcooked* can be discussed mainly through four lenses: problem-solving, flow, cooperation, and beauty. According to Schell (2019), a game is a problem-solving activity approached with a playful and voluntary attitude. The game must thus present its objectives clearly and impose rules so that players can devise strategies to solve the proposed problem based on their previous experiences. In *Overcooked*, this approach is taken to the extreme. Players are constantly presented with new issues and forced to devise new strategies, either because new orders continually arrive in the kitchen or because of sudden changes in the setting. When applied well, this approach is essential for keeping players focused and for making the gaming experience enjoyable and rewarding. Conversely, if poorly used, it can frustrate the player and cause disinterest. Note that a certain level of frustration is desirable for players to realize that some

strategies may not work. In *ReciCaos*, each difficulty level presents players with different challenges and objectives. At each level, players have to deal with new types of solid waste, each with its characteristics. In addition, the four levels feature different layouts of the elements in the scenario, forcing players to change their strategies between them. The types of waste presented at each level are 1 – paper; 2 – paper and metal; 3 – metal and glass; 4 – paper, metal, glass, and plastic.

Csikszentmihalyi (1990) argues that it is necessary for players to keep in the "flow channel" to stay focused and engaged with the activities, which, according to his theory, is one of the secrets of satisfaction during the game. This theory is used in games to balance the difficulty in an intermediate situation between boredom (game too easy) and anxiety (game too complex) to maintain a balance. For Schell (2019), this constant cycle between "tension and relaxation" seems to be natural for human beings. Moving between these two states gives players the pleasure of variety and anticipation. The *ReciCaos* game project seeks to respect this idea by allowing players to develop their skills before proposing new challenges. This is always done at the overload threshold, forcing the player to look for new strategies to achieve a minimum score before moving on to the next level. As Schell (2019) emphasizes, collaborating and succeeding in a game creates deep social bonds between players. *Overcooked* needs this cooperation and trust to work. The overload of tasks directed at a single player would invariably result in frustration, but dividing these tasks between players can create collective enjoyment when successful. From this perspective, *ReciCaos* was developed to be primarily a two-player cooperative game. The layout of the elements at each level was designed so that two players would be sharing the tasks (Figure 2).

Figure 2. An example of a level divided into two areas in the *ReciCaos* game. Source: The authors.

Overcooked has an artistic design categorized as Low Poly. In this type of graphic art, the 3D models have few polygons and a low level of texturing, giving the game a more informal and playful look while facilitating the process of creating assets. Despite the low level of detail, this artistic design can be stunning and attractive when implemented consistently. Schell (2019) emphasizes that the more beautiful the art used to present an experience – be it written art, music, dance, acting, comedy, cinematography, graphic design, or any other form of expression – the more exciting and engaging it will be for players. Like *Overcooked* and its comedic nature, the Low Poly aesthetic in the game design of *ReciCaos* is perfectly appropriate and contributes significantly to making the game more attractive, fun, and enjoyable for different ages.

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3.2 Participants and Method Description

An empirical study was conducted to evaluate the game by applying a questionnaire inspired by Carvalho *et al*. (2023) and aimed at the general public. Thirty-one participants, twenty-six men and five women, took part in the study, with an average age of 22.6 (SD = 4.7). Of these, 29 participants said they played digital games at least once a week. As the game was developed with this public in mind, conducting this study without restricting the number of participants was important in this first evaluation. This initially allowed checking whether the game was enjoyable, fun, and easy to understand, and whether the environmental theme was addressed clearly and objectively. A Google Forms was created to organize all the instructions for the participants. It contained directions and links on how to get the game, install and run it, and, of course, the questionnaire to be answered. The questionnaire was designed to be self-contained to minimize the participants' effort. The form was disseminated in the social networks of the researchers involved and in the Federal University of Itajubá (UNIFEI) university environment. All those who contributed to the evaluation were anonymous volunteers who signed an Informed Consent Form (ICF). No sensitive data was collected, such as name, e-mail address, or other identification information. In addition, before the form was released, it underwent a pilot test with two people to refine it. Participants took the following steps to complete the evaluation: 1) accessing the questionnaire link; 2) from the questionnaire, accessing the link to download and install the game; 3) playing and completing all the phases; 4) answering the questionnaire.

The questionnaire can be divided into two parts. The first contained objective questions and was constructed following a strategy adapted from the MEEGA+ model (PETRI *et al*., 2019). This model is well-known in informatics in education and is widely used to evaluate educational games. It can be subdivided into four criteria: Usability, Player Experience, Challenge, and Social Interaction. The authors of this research selected which questions would be most appropriate for the game and the target audience and adapted some to make them more coherent with the game context. It can therefore be said that an adaptation of the MEEGA+ model was used. The questions used a five-point Likert scale (JOSHI *et al*., 2015), ranging from "strongly disagree" to "strongly agree." The first part of the questionnaire (with the four criteria evaluated) contains 21 questions (Table 1). Each question has an identifier.

The first nine questions (U1 to U9) aim to assess the game's usability, playability, and, above all, attractiveness, which is one of the main objectives of this work. Questions PE1 to PE6 aim to determine if participants enjoyed the game and believe it can be used as a teaching resource. Questions C1 to C4 highlight another essential part of the questionnaire: the game's difficulty. As this is a game aimed at the general public, assessing the difficulty level presented to the player is essential to determine if the game is suitable for all ages. Excessive difficulty can cause unnecessary frustration, leading players to lose interest (SCHELL, 2019) and, consequently, in the educational theme addressed. Since the game offers the possibility of playing in pairs, two questions (SI1 and SI2) were incorporated into the questionnaire to analyze the social interaction proposed by the game. These questions could only be answered by participants who played in cooperative mode. They assessed if participants could cooperate to solve problems and if this cooperation was enjoyable. In the study conducted, twenty participants answered these questions.

The second part of the evaluation process presented three open questions in which the participants could freely discuss what they thought was good or bad about the game:

1) What did you like about the game?; 2) What was inadequate in your opinion?; 3) Leave a comment, suggestion or criticism about the game.

Table 1. Questionnaire adapted from the MEEGA+ model (continued). Source: Adapted from Petri *et al*. (2019).

Criteria		Question
Usability	U1	The game design is attractive.
	U2	The texts, colors, and fonts match and are consistent.
	U3	I only had to learn a few things to be able to start playing the game.
	U4	Learning to play this game was easy for me.
	U5	I think most people would learn to play this game quickly.
	U6	I think the game is easy to play.
	U7	The rules of the game are clear and understandable.
	U8	The fonts (size and style) used in the game are legible.
	U9	The colors used in the game are understandable.
Player Experience	PE1	I enjoyed this game.
	PE2	Something happened during the game that made me smile.
	PE3	I was so involved in the game that I lost track of time.
	PE4	I forgot about my surroundings while I was playing this game.
	PE5	It is clear how the game content relates to the subject.
	PE6	I believe this game can be used as a teaching resource.
Challenge	C1	This game is suitably challenging for me.
	C2	The game offers new challenges (it offers new obstacles, situations, or variations) at an appropriate pace.
	C3	The game does not become monotonous in its tasks (repetitive or tedious tasks).
	C4	Completing the tasks in the game gave me a feeling of accomplishment.
Social Interaction	SI1	The game promotes moments of cooperation and/or competition between the players.
	SI2	I felt comfortable interacting with other people during the game.

4. RESULTS AND DISCUSSION

This subsection presents the results and discusses the observations made in the study, which involved 31 volunteers. The results are addressed according to each criterion in the questionnaire. Regarding 'Usability,' questions U1, U2, U8, and U9 (Figure 3) dealt with visual and artistic design, one of the game's most important aspects.

Based on the opinions expressed, 90% of the participants agreed or totally agreed that the aesthetics applied are attractive and have consistent and understandable colors and texts. Thus, the chosen Low Poly aesthetic was appropriate and successfully applied, as it attracted the attention of adult players, fulfilling one of the research objectives. Questions U3-U7 measured how easy was to play and learn the game. The answers to these questions indicated that most participants agreed or totally agreed that the game rules are clear and that it is easy to learn how to play. However, 45% of the participants in question U6 did not find ReciCaos to be an easy game. Therefore, it is understood that the game is easy to learn, which is necessary to reach audiences of different ages. However, a conflict arises, as many players found the game's difficult too high.
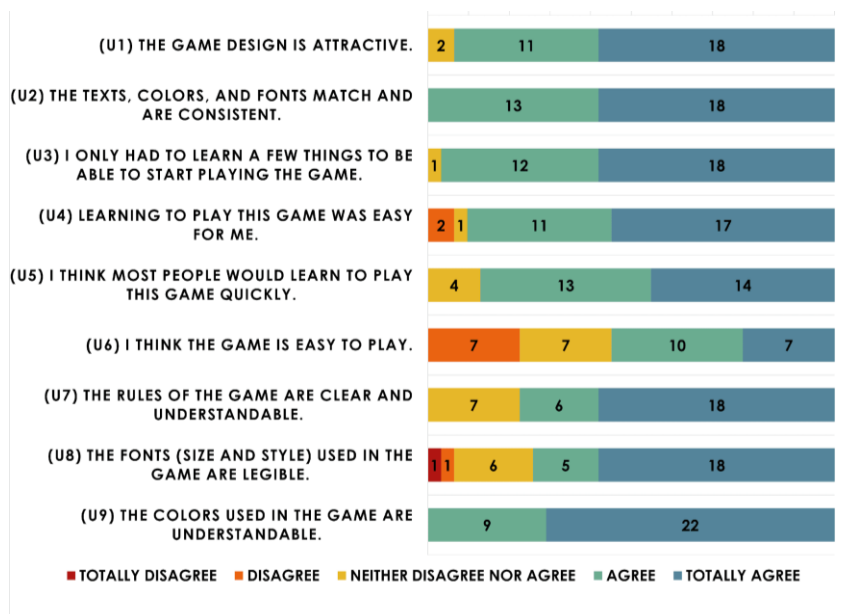
Figure 3. Answers to the Usability criterion. Source: The authors.

Six questions were asked to analyze the Player Experience. Figure 4 shows the result of the opinions expressed about this criterion. As can be seen from the answers to questions PE1 and PE2, 94% of the participants found the game fun and 87% enjoyed playing it. However, the answers to questions PE3 and PE4 show that approximately 32% of the participants did not find the game immersive. Although the game is fun, it can be inferred that design flaws caused a loss of interest for some players or the difficulty as too high, as reflected in the answers to question U6. Regarding the didactic content covered, questions PE5 and PE6 showed that most participants identified the didactic content presented and agreed or totally agreed that the game could be used as an educational resource. The game is thus understood to perform its educational role adequately.
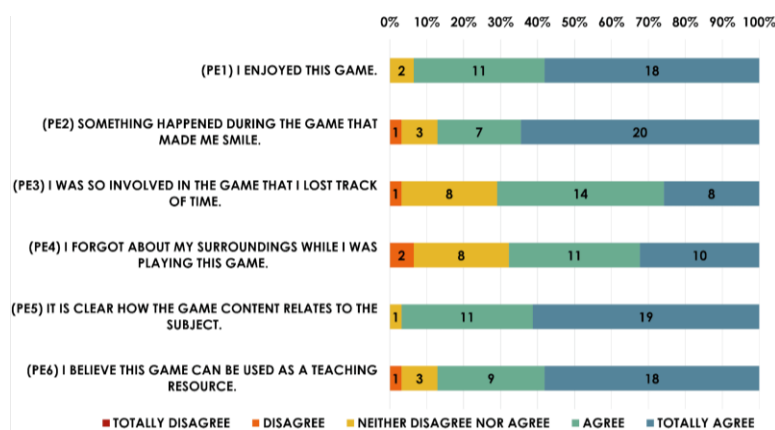

Figure 4. Answers to the Player Experience criterion. Source: The authors.

Four questions were proposed to analyze how challenging the game is (Figure 5). The responses to question C1 indicated that 29% of participants did not find the game's difficulty suitable for them and that 35% of the responses to question C2 indicated the game did not offer an appropriate pace of challenge. When combined with the responses to questions U4 and U6 about ease of play, it is clear that the game was challenging for some participants. The answers to questions C3 and C4 revealed that approximately 32% of the participants found the game monotonous and felt they needed more sense of

accomplishment when completing the tasks. Thus, it can be inferred that the game offers a high challenge to players but needs to provide a clear and satisfactory reward for each task completed. Two questions were proposed to the participants who played in pairs to analyze the social aspect of the game (Figure 6). For this aspect, ten pairs of participants played. The answers to question S1 show that 90% of the participants agreed or strongly agreed that the game promotes cooperation. The answer to S2 shows that 92% felt comfortable playing with their colleagues.
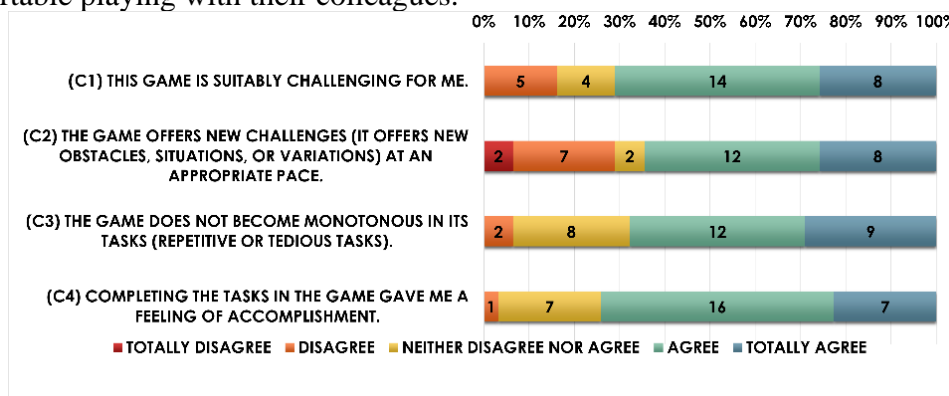

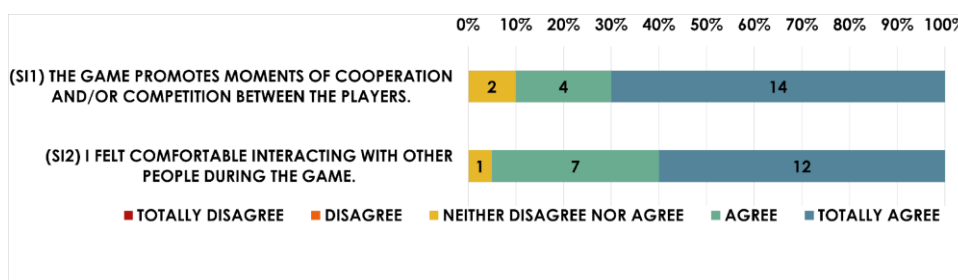**Figure 5.** Answers to the Challenge criterion. Source: The authors.

Figure 6. Answers to the Social Interaction criterion. Source: The authors.

In the questionnaire, participants were allowed to express their comments on the game. In response to "What did you like about the game?", several comments pointed to the ease of learning to play and the aesthetics of the game, as in the comment, "*The game is quite simple, being extremely easy to pick up and play, even for more casual players due to its effortless control and objectives. The game's visuals and audio are also very pleasant*". Many comments highlighted the similarities between *Overcooked* and *ReciCaos*. One of the participants commented, "*The game is very creative in reusing some mechanics from Overcooked and is fun to play*," and, in another comment, "*I love Overcooked, so seeing a game with similar gameplay caught my attention.*" These comments reaffirm the inference that the chosen Low Poly artistic design was appropriate and successfully implemented. In addition, some participants made positive comments about the educational aspect of the game, such as "*The theme and clear inspiration with Overcooked was something exciting; it could very well be a way to teach the separation of waste according to its types to young children (end of Elementary School I to Elementary School II)*" and also in an excerpt from the comment "[...] *As someone who recently graduated, I know that the game hit the nail on the head in the educational aspect, allowing us to work on a very important topic today, in a simple and fun way. The game would perfectly fit into a lesson plan or teaching sequence on sustainability and recycling* [...]", thus reinforcing the inference that the game has played its educational role.

Considering the question, "What did you consider bad?", most comments pointed out issues with the controls and the lack of visual feedback for some actions, such as, "*I

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found it bad that there is no 'load action' indicator, such as to throw an object away or in the brief interval between interacting with the glass/plastic recycling machine and the machine starting to recycle." These problems have been mapped and could be used as suggestions for improvements in future work. Another criticism was the game's difficulty. Taking the following comment as an example: "*The main criticism I have of the game is the difficulty when playing individually. The spawn time of the items is too short for those who play alone.*" We can see that the participants faced difficulties when playing alone. This is because the game was initially designed for cooperative, two-player mode. As such, many phases may have presented an unwanted workload, possibly causing frustration for the players. Therefore, the game features a visually pleasing environment and clearly presents the educational content. However, some players found it challenging. Specific player profiles who seek this type of experience highly value demanding games. Nevertheless, this feature needs improvement within the context of an educational game.

A limitation encountered during this evaluation was validating the game's cooperative mode, as there were too few participants playing in pairs to carry out a consistent analysis of the social interaction aspect provided by the game. A possible improvement would be to implement an online cooperative mode to allow players to get the experience in pairs, each playing on his/her own computer. An alternative to implementing the online cooperative mode would be to carry out the validation in person, with equipment suitable for running the game.

5. FINAL CONSIDERATIONS

With ecological awareness and environmental education as a foundation, this work aimed to approach the selective collection of solid waste in a playful, attractive, and fun way for the general public, not restricted to children. Inspired by the booming commercial game *Overcooked*, we proposed developing the digital educational game *ReciCaos*, where the player's main objective is to perform selective solid waste collection, by using the recycling colors and not allowing the waste to be incinerated. To guide the game design, we structured it around four lenses: (i) problem-solving, (ii) flow, (iii) cooperation, and (iv) beauty. A questionnaire was applied to test the game development and to investigate the perceptions of volunteer participants regarding its use. The criteria evaluated on this occasion were usability, player experience, challenge, and social interaction. The evaluation revealed that the game can be used as an educational tool, as it is easy to learn and play, in addition to being pleasant and visually appealing. However, it was also noted that the game had problems with the controls and was too difficult for some participants. Thus, it can be concluded that digital games in education are not restricted to children but can be aimed at young people or adults if they have attractive elements. The low-poly design was observed to be pleasant and gave the game a beautiful look/layout. Finally, it was noted that the "chaos" mechanic has great potential but needs to be balanced. For future work, the suggestion is that the difficulty be better balanced. Although it is an arduous task, properly balancing an educational game is crucial if the player is to keep interested.

The following are some of the relevant suggestions made by the participants: including information about the educational topic covered between the phases; together with a teacher, producing a didactic sequence for the topic covered using the game; implementing interactive tutorials; including a menu for selecting the difficulty; including a menu for mapping controls; including the possibility of playing with joysticks; providing adequate visual and audio feedback for the player's actions.

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