Game Development for Learning: An Educational Themed Game Design Approach

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Abstract. Introduction*: In serious games or more specifically, educational games, maintaining a critical balance between gaming and didactic elements is quite a challenge. Current serious games quite often harness educational potential of games, favoring the player experiences above learning efficacy. These games may neglect the knowledge established in instructional design or try to prioritize educational information without seamlessly integrating it to the game.* ***Objective:*** *This work presents a rapid development approach of an educational game about the Brazilian electrical system and sustainability, describing some possible approaches that can be used to maintain the playful aspect, prioritizing learning and maintaining a seamless design.* ***Methodology:*** *Although the game, called SustenPata: Uma Aventura Eletrizante was built upon the electrical system and sustainability subject, the strategies and design employed can also be used in digital games that address other educational subjects.* ***Results:*** *The game was tested and endorsed by middle school students, in addition to being selected as the best game at GamethONS competition 2023.*
Keywords *Educational Game Development, Game Design, Brazilian Electrical System*

1. Introduction

The need for interactive contents that can make the most of the potential that technological advances offer is, in part, filled by games or educational games. Educational games have been around for quite some time. Such serious games have indeed been widely accepted as effective educational tools [Peña-Miguel Noemí 2014]. Games are mostly valued for their motivational power, i.e., the ability of hooking and absorbing players in such a way that learning becomes fun [Csikszentmihalyi 1990, de Freitas 2006]. In serious games — games that utilize computer gaming and simulation approaches and/or technologies for primarily non-entertainment purposes — players can be challenged in order to enhance creativity and actively engage in problem solving, goal formation, and critical or strategic analysis.

1.1. Brazilian Electrical System

The Brazilian electrical system is currently the largest in Latin America and ranks eighth among the largest electricity consumers in the world [Energética 2023]. The National Interconnected System (SIN) is operated by the National Electric System Operator (ONS) and regulated by the National Electric Energy Agency (ANEEL). The dependence on thermoelectric plants and fossil fuels [ANEEL 2018], among other factors, directly

contributes to the increase in greenhouse gas (GHG) emissions. However, proposing solutions for the electrical system is not a trivial task; it requires a comprehensive understanding of the system as a whole considering everything from technical to environmental and social aspects. In this sense, there are a series of medium and long-term challenges unknown to a large part of the population, such as the imbalance between supply and demand and the difficulty in recovering investments [Arthur Ramos 2019]. Knowing these challenges and why they exist is essential for future generations to propose innovative and sustainable solutions, which requires an integrated approach. The adoption of educational games on this topic is one of the efficient awareness strategies that can be employed.

1.2. Games and Education

Today's children should be the creative individuals who produce innovation, rather than just consuming digital content offered to them. For this reason, students need to improve their creative thinking skills [D. Bulut 2022]. Since playing games is one of the most important activities during this screen time, it cannot be ignored as a potential tool for improving student learning or skills.

One popular technique among researchers is the game-based learning approach (GBL) [Tamosevicius 2022]. Following a learning-through-practice and experimentation approach, GBL is rooted on constructivist pedagogical theory [Zamzami Zainuddin 2020]. The effectiveness of learning through experimentation was also reinforced by Dale, who grouped the active learning process in a hierarchical way.In his model, conducting experiments, teaching, and creating links with instructional content were considered the most successful ways of gaining knowledge [Edgar 1969]. Dale's learning pyramid is illustrated in Figure 1.

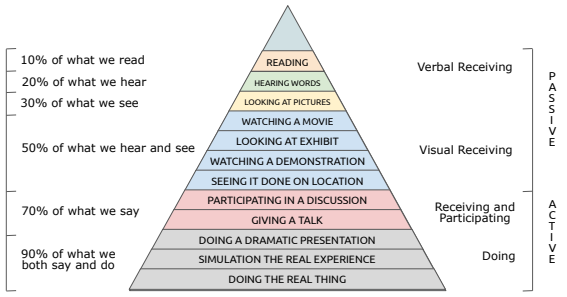

Figure 1. Dale's pyramid with its subdivisions.

Although over the years much skepticism among academics has disappeared due to the increasing number of examples of successful serious games that have become available, the serious games industry may still exhibit many characteristics of an emerging and immature business branch. These include numerous small companies with weak interconnections, a lack of harmonizing standards, limited division of labor, and insufficient evidence of product effectiveness.[W. Westera 2019, J. Stewart 2013].

This work reports on a rapid development approach for educational games, specifically addressing the the Brazilian electrical system and sustainability. The approach proposes an agile development method for educational games, based on design

and game development skills of RPG entertainment games, but aiming to prevent game design from being dominated by game mechanics rather than didactic principles. The electrical system theme was initially motivated by the launch of the GamethONS 2023 challenge, promoted by the ONS. Although the game in this article focuses on the electrical system and sustainability, the strategies employed during its design and development can be applied to digital games covering other educational subjects.

2. Related Work

For some time, education researchers have emphasized the importance of games as an essential resource for students to learn naturally and enjoyably, given their inherently playful nature [Magda A. de O. Franco 2018]. Even before the widespread adoption of digital games, authors like Vygotsky [Vygotsky 2007] highlighted the significance of play in child development. In fact, the discussion about the importance of games in the teaching and learning process is a recurring theme. Games are not only discussed by renowned authors in the field but are also addressed and recommended in the National Curricular Parameters as an auxiliary resource for learning [Drielly Adrean Batista 2012]. The creation, application, or pedagogical evaluation of digital games has been approached from a variety of knowledge areas. Calderón and Ruiz [A. Calderón 2015] conducted a systematic literature review on the evaluation of serious games, summarizing the current state-of-the-art regarding the different methods and procedures used to assess them.

Regarding the topic of electricity and education, Chen et al. [S. W. Chen 2019] created a digital game on the subject and compared the results with traditional learning methods using pencil and paper. The authors reported that participants using the digital game achieved significantly higher test scores than groups that used a low-complexity game or traditional pencil-and-paper methodologies.

3. Methodology

3.1. Game Design and Implementation Aspects

The methodology described here was used to develop a game within a four-month timeline with a small team of three people. This approach was not designed for large-scale commercial game development, but rather for a shorter, agile development cycle. Figure 2 presents a general overview of the game creation process. Briefly, the initial steps of the project involve the Game Design Document (GDD). [Adams 2010]. The chosen model for the document was the canvas format, which briefly discussed and documented the following points: General Game Concept, Target Audience, Platform, Characters and NPCs, World and Scenarios, Gameplay, Mechanics and Powers, Game Flow, and Interface and Control. Before the codification of the software artifact began, the team studied and researched – for approximately 1 month – subjects on 4 specific topics: The path of energy distribution, the role of the ONS, sustainability, game design and introduction to the *GDevelop5* game engine. Before beginning the software artifact's codification, the team dedicated approximately one month to studying and researching four specific topics: the path of energy distribution, the role of the ONS, sustainability, game design, and an introduction to the *GDevelop5* game engine. During the foundation and creation of the GDD, themes were grouped into three main chapters, one for each subject: awareness regarding the proper use of electricity, challenges in the electricity sector, and energy sustainability.

This chapter separation was designed to address educational topics more systematically and allow for content correlation within subcategories. For example, one student might focus on issues related to conscious energy use, while another would cover topics such as transmission, commercialization, and energy infrastructure challenges. Additionally, this approach prevented the repetition of topics from the same subcategory throughout the game, allowing each team member to be responsible for defining the content of one area without the risk of another repeatedly addressing the same topic.

In this RPG game genre, the main character freely navigates through scenarios and interacts with non-player characters (NPCs), informational objects, and items. A single implementation of player actions and movement applies to all game chapters. Similarly, the code governing interactions with items, NPCs, and dialogues shares the same fundamental structure, requiring only modifications to the art, texts, and action contexts. Through these interactions, the player obtains relevant information about the topic or initiates confrontations with NPCs to convince them to adopt more sustainable energy use practices, appropriate to current societal standards.

The game's plot is set in a fictional fable-like world that reflects the current conditions of the Brazilian energy sector. In this scenario, the inhabitants are dogs and other humanoid animals. Animal-based characters were chosen to evoke player empathy and avoid unintended associations with real individuals. The protagonist, a dog, must face challenges related to energy sustainability, seeking solutions to strengthen civic engagement. These challenges range from convincing NPCs to use electricity consciously to acquiring items that enhance the character's knowledge or skills. The game world is divided into four scenarios or chapters: I - The Challenge of Energy Valorization; II - Challenges of the Brazilian Electric Sector; III - Sustainable Local Development; and IV - The Final Challenge. Each of the four regions, corresponding to a chapter, is based on real Brazilian locations: Centro: An urban center where the school, the ONS headquarters, and the protagonist's house are located; Monte Belo: A picturesque region characterized by large rivers, refreshing winds, and abundant light. This area houses the country's primary energy-generating sources; Lençóis Caninos: A predominantly rural region where the population lives by subsistence. It features desert areas, rocky mountains, and some oases; Cãotanal: The oldest region in the country, known for its flooded areas and formerly

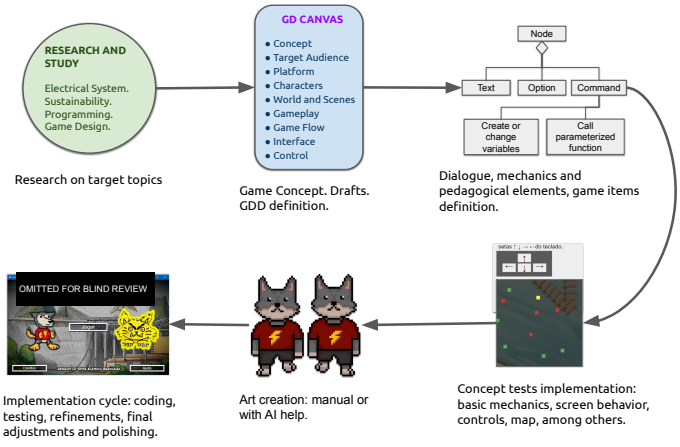

Figure 2. Flowchart of the general steps adopted in creating the game.

the greatest diversity of animals and plants. However, access to this region is currently blocked, and its status is unknown. A cloud of pollution and dead fish carried by the current emanate from this last region. Each chapter addresses a specific subject within the game's narrative.

3.2. Game Mechanics

The first three chapters of the game can be accessed freely, However, the final chapter (IV) can only be unlocked upon maximizing an "efficient and sustainable energy production" bar, which requires completing all challenges in chapters I, II, and III. When confronting an NPC, combat proceeds in a turn-based RPG style via a selection menu. The available options for each confrontation vary based on the NPC's characteristics. For instance, players can choose between an aggressive attack or presenting a specific argument against the opponent's justification. Actions deemed incorrect by the game drain the player's energy, whereas appropriate actions decrease the enemy's energy.

The confrontation mechanic always involves an argumentative or physical battle, framed within the context of valorization, sustainability, or challenges in the electricity sector. Each NPC requires unique strategies. The flow of dialogue and player options are represented through a graph, and are distinct for each challenge. Besides confrontation events, players can acquire items that provide information about best practices in energy use and generation. Defeating an NPC or collecting an item increases a bar representing efficient and sustainable energy production. Once this bar is completely filled, access to the final Chapter IV is granted.

3.3. Educational Aspects

Much of the pedagogical instruction is conveyed through dialogues, where the protagonist persuades other NPCs to adopt sound energy usage practices or informs them about characteristics of energy matrices. The game itself guides player progress, providing feedback on choices without requiring a teacher or a guided class. The educational aspect has been a major focus of the game. While some authors [C. Linehan 2011, E. A. Boyle 2016] have highlighted persistent weaknesses in serious game design—specifically, unclear didactic foundations and a lack of empirical effect studies—a comprehensive overview of didactic pitfalls, supported by established research on learning and instruction, is not yet available [Westera 2022]. A key concern from the conceptualization phase was to prevent the game from resembling a formal class, a simple booklet, or an educational quiz, as these factors could inevitably break player immersion. After developing the dialogues, we aimed for a harmonious design balancing playful and educational elements. This was achieved by creating interaction flows that combined dialogues with diverse, context-specific actions, which aided in both the verbal and non-verbal communication of the theme (Figure 3). Player engagement and motivation can be directly linked to a game's objectives and mechanics. Intrinsic motivation is enhanced when three basic psychological needs are met: autonomy, competence, and relatedness. It is suggested that satisfying any one of these needs is likely to increase an individual's sense of intrinsic motivation [E. L Deci 2004]:

- Need for Autonomy: In education, autonomy refers to the absence of external pressure forcing learners to act or behave in a certain way during the learning

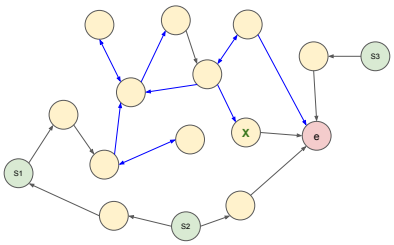

Figure 3. Example of the game dialog structure. In the picture, S1, S2 and S3 are starting conversation nodes for map dialog, combat dialogue and post success dialogue, respectively. From a node it is possible to move to a new node (black arrows) or decide between more than one option (blue arrows). The decision may depend on the player's choice or variables activated during the traversal in the graph.

process. Within the game, every decision and action results from the player's choices. Incorrect actions are "punished", while correct ones advance progress.

- Need for Relatedness: The need for relatedness is met when individuals feel they belong to a particular group. The game's main character embarks on a journey for the collective good; after each successful confrontation with an NPC, the protagonist gains an ally for the cause, forming a group pursuing a common goal. The game's final challenge also addresses this shared objective.
- Need for Competence: The need for competence refers to the feeling of successfully mastering a particular task or activity. This is achieved through the game's confrontations. Players must strategize to overcome challengers, sometimes through actions and other times through dialogue. Successful players are awarded a sustainability point, which is essential for reaching the game's conclusion.

Besides the motivational aspect, the game design adhered to several basic guidelines from Steve Rabin's *Introduction to Game Design* [Rabin 2012]. While these concepts aren't new, they served as a starting point for developing and testing ideas. Additionally, the following tips proposed by Ledda [Ledda 2012] were considered:

1. **Align game types with learning outcomes** In the game, the player takes the lead, encountering and interacting with a group of other characters to build a story. This genre also heavily features dialogue, which facilitates the conveyance of educational information to the player.
2. **Turn learning and knowledge into the clue** During character encounters, the dialogue flow and progression provide feedback to the player. For each character, the dialogue either progresses or fails based on the player's adjusted actions. Should the player make a significant error, a large amount of energy is lost; however, minor mistakes result in only a small energy reduction. An interesting learning-related aspect of the game lies in its challenges, which are structured as decision graphs. Players must pay close attention to the dialogue flow and events to progress. Several loops or repetition structures within the dialogues effectively prevent players from advancing merely by "guessing" answers. This design is crucial for imparting the intended knowledge.
3. **Apply proven effective instructional strategies to design the game** As an instructional strategy, the dialogues are generally not direct questions. All were

designed to mimic everyday conversations, using simple language and rhymes. Additionally, some choices implicitly describe the reason for an error or success.

4. **Guide the gamer to achieve goals** Within the outdoor sections of each of the three main chapters, a mini-map is located in the upper left corner, indicating approximate regions containing items, challenges, or passages. This ensures players are never left aimlessly exploring without awareness of remaining objectives within that chapter. Notably, a map was necessary only due to the flexibility of completing objectives in any order. If the game mandated a specific priority among objectives, the game design itself would ideally guide the event progression in an orderly manner. The mini-map was implemented with a configurable size and automatically identifies items, confrontation locations, and passages. As soon as an item is collected or a confrontation is won, its corresponding marker is removed from the mini-map.
5. **The game must be immersive** The game's items are all related to real-life concepts, and its chapters represent regions mirroring diverse Brazilian environments, including rural, urban, and power plant settings (Figure 4). Additionally, the final enemy, the "energy cat", serves as a metaphor for clandestine energy connections in Brazil, colloquially known as "*gato de luz*."
6. **The game must be challenging, but neither so easy or extremely difficult** Players may require an initial adjustment period at the beginning of the game. Following this introductory phase, they will seek challenges to continue playing. The primary challenge arises from the fact that specific educational topics change with each chapter, meaning players face a non-cumulative challenge in each. Difficulty progression in this work is not linear, as players are free to visit each of the chapters in any order, with the exception of the final challenge. To break the routine of the most common mechanics, other gameplay elements are introduced, such as collecting items to gain access to specific areas or navigating certain points with precise movements to avoid falling into a river.
7. **The game must be reliable** The most important aspect is to focus on the learning outcomes. According to the gd.games website, where the game is hosted, the game currently boasts over 970 plays. It's crucial to highlight that while the game's mechanics were tested throughout development, the final week was exclusively dedicated to comprehensive testing and bug identification. An undetected fatal bug could derail the entire game.

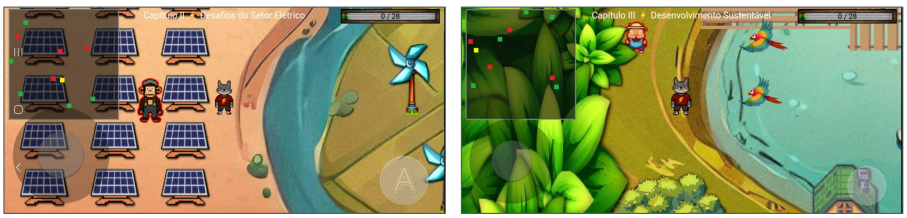

Figure 4. Screenshots from regions in the game, running on a smartphone. On the left, the chapter with power plants, on the right a chapter representing Brazilian's preserved rural environments.

3.4. Creation of Audiovisual Assets

Initially, some concept tests utilized both graphic drawing and pixel art styles. After mapping the team members' skills, a mixed style of high and low-resolution pixel art was

adopted. Given the current evolution of artificial intelligence (AI) and neural networks in image generation tasks, generative neural networks were used to create some game backgrounds, which were later edited manually or using free editing tools. At the time, Bing Image Creator was chosen as the generative network, primarily due to its free nature and ease of use. Only secondary assets were generated; the main character and key features related to the primary theme were created manually. It's worth noting that the raw images generated by the AI never perfectly matched the desired outcome. All required manual modification by the team, which introduced additional work. Small furniture for indoor scenes and some buildings were sourced from free, unrestricted-use platforms. All third-party resources used are listed in the game's credits. Sound effects were mostly obtained from free, unrestricted-use sources. The game's songs, featuring simple melodies reminiscent of old 8-bit and 16-bit video games, were composed by a student using the FL Studio tool.

4. Results and Discussions

The final artifact is a complete game covering a considerable number of topics related to the Brazilian electrical system. Players must acquire 28 points to fill the sustainability bar, the game's main objective. Of these, 12 are earned through dialogue confrontations (13 including the final confrontation), and 16 from collectible items related to energy and sustainability. Developed using the GDevelop5 game engine, the game nowadays supports web, mobile, or executable versions. To evaluate and make the game accessible to students and the general public, a web version—playable in any modern web browser—is freely published and available on gd.games and itch.io channels (Figure 5). The game is accessible online via any modern browser on desktop or mobile devices and supports touchscreens, keyboards, and standard Xbox, Nintendo Switch, or PlayStation controllers.

Figure 5. On the left, the itch.io game link. On the right, the gd.games game link

Evaluating the effectiveness of an educational game is a multifaceted process. In this case, it involved analyzing aspects ranging from the game's construction to its impact on learning. As an evaluation instrument, the game was made available for testing in two technical high school classes, serving as a complementary activity on citizenship and sustainability. Students were invited to play while the teacher observed their behaviors and interactions. Despite observing, the teacher did not intervene in student interactions. After finishing playing, giving up, or losing interest, students were asked to complete a *Google Forms* questionnaire containing qualitative and quantitative questions. The target audience tested consisted of students aged 14 to 17, enrolled in integrated IT high school. The evaluation took place in the computer laboratory where their regular computer classes are held. In total, 47 forms were answered. The time spent playing the game until completion varied from 60 to just over 120 minutes, with an overall average of approximately 80 minutes.

For quantitative evaluation, questionnaires incorporating open-ended questions and a Likert scale were employed. The Likert scale offers a simple and effective method for collecting quantitative data on individuals' sentiments; it presents a statement and asks participants to indicate their degree of agreement or disagreement. For qualitative evaluation, open-ended questions, recurring patterns, observations, and conversations with students following the evaluation and questionnaire closure were utilized. The questions and observations aim to assess the following aspects of the game and its construction: **Game design assessment**— includes evaluating the suitability of visual, audio, and interactive elements for achieving the learning objectives, as well as the coherence between game elements and educational content. **Learning assessment**— focuses on student perceptions of the game, their ease of learning, and the relevance of the content presented. **Assessment of Motivation, Engagement and player experience** — involves gathering qualitative insights into the game by observing student engagement during gameplay, their interactions, and utilizing open-ended questions for students to express their opinions and further inquiries. The students were not asked to consider only educational or non-commercial games, i.e., there was a good level of acceptance even considering the students' previous experience with modern and commercial games. As can be seen in figure 6, the criteria for visual quality, sound quality and usability were considered good.

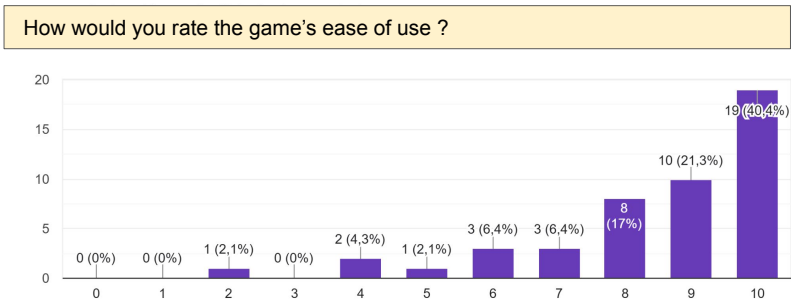

Figure 6. Graph related to design aspect of the game questioning, with 47 responses. The scale ranges from 0 (worst) to 10 (best)

Part of the perceived learning is evident in Figure 7. When queried about the game's educational capacity, the vast majority of students considered the game to be highly educational regarding the topic. In response to the questionnaire item, “While playing, were you able to absorb any interesting and useful information about the topic of energy and sustainability?”, all 47 participants answered “yes”. Of these, 51% further elaborated and specified the type of information acquired.

About 59.6% of the students fully completed the game. The reasons cited for non-completion varied but were justified, ranging from game difficulty to issues with the internet connection. Notably, 75.4% of students reported never having played an educational game before. Although only 18 participants responded to the open-ended question on this topic, all of them expressed positive opinions about the game.

Beyond the methodological evaluation, the game effectively delivers its educational task without sacrificing its playful nature. This was reinforced by evaluations and feedback from the GamethONS 2023 challenge, where the game secured first place,

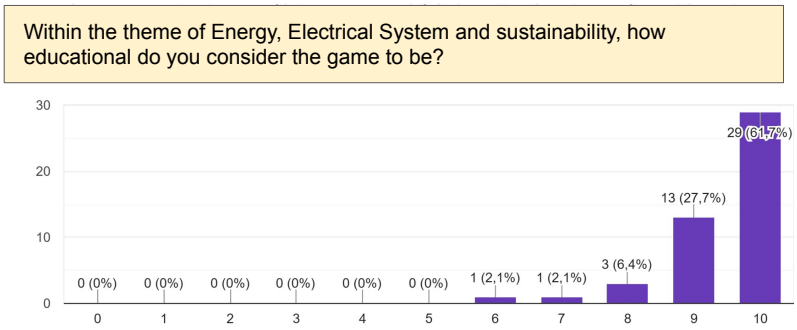

Figure 7. Graph related to answers the educational aspect of the game questioning, with 47 responses. The scale ranges from 0 (worst) to 10 (best)

competing against over 30 other games on the same theme. The evaluation criteria included gameplay, originality, coherence, and suitability to the theme. In addition to the product's quality, the development process was crucial for engaging students with topics related to the Brazilian electrical system, sustainability, and characteristics of major Brazilian energy matrices, among other connected subjects. From a technological standpoint, developing a digital game presented a significant technical challenge; its implementation aspects were demanding and required extensive learning.

5. Conclusion and Future Work

The developed game serves as a tool for disseminating knowledge about the electricity sector. It also provided an opportunity to advance technological understanding, strengthen sustainable socio-environmental initiatives, and encourage co-responsibility among civil society actors, particularly literate children and adolescents in their social formation phase. More importantly than the game itself are the lessons learned and the potential to apply similar approaches to create educational games on other crucial topics beyond the electrical system and energy sustainability. An additional point of interest is that 76% of students enrolled in the integrated technical course in computing were able to identify technologies and techniques present in their curriculum within the game.

The overall development process was challenging, primarily due to the tight deadline. The teacher occasionally had to intervene to manage new ideas or artwork proposed by students, who sometimes lost track of project timelines and context. The use of AI for generating some secondary images and the decision to implement a base framework for game mechanics were crucial in meeting this deadline.

As for future work, we intend to replace third-party assets with original artwork and translate the game into English, as only a Brazilian Portuguese version currently exists. We also plan to implement a more in-depth evaluation of the results, employing descriptive statistics, increasing the number of participating students, and defining control groups

Acknowledments

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