

RESEARCH PAPER

A Serious Narrative Game Combined with Data Visualization to Aid in the Development of Skills and Competencies in the Management of Infectious Diseases

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Abstract. *Background:* The spread of infectious diseases causes saturation in public health services, putting pressure on hospital admissions and generating high costs resulting from prolonged and intensive treatments. In this context, health managers can combine concepts from serious games, narrative techniques, and data visualization to support decision-making when analyzing public health data for epidemiological surveillance. *Purpose:* A serious narrative game, combined with spatiotemporal data visualization and usability concepts, aimed to assist in the development of students' skills and competencies in infectious disease management. As a case study, we developed an urban setting focused on the spread of dengue fever. *Methods:* The game was developed using the User-Centered Design method, with the participation of a professor from a Health Management undergraduate course and his students. They contributed to aligning the narrative with real-world management practices in public health, as well as to evaluating the game's usability using the System Usability Scale. *Results:* The developed game prototype allows the application of interactive narratives to the training of skills and competencies in combating infectious diseases. By combining elements of narrative games with visualization and interaction with spatiotemporal data, the game simulates plausible scenarios and seeks to encourage the strategic management of resources and actions in public health. *Conclusion:* This study presented the design and development of a narrative game that, combined with spatiotemporal data visualization techniques, demonstrated potential to support the training of health management students in the management of infectious diseases, specifically dengue. A usability evaluation of the game revealed that participants approved of the concept. It should be noted, however, that this study does not present an assessment of the subjects' actual learning following the use of the proposed game.

Keywords: Serious Narrative Game, Infectious Disease, Data Visualization, Usability, Health Management

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1 Introduction

Infectious diseases, such as influenza, dengue fever, COVID-19, measles, and tuberculosis, pose persistent challenges to global public health because they are highly transmissible via an intermediate agent [van Seventer and Hochberg, 2017]. In Brazil, for example, increases in dengue cases cause overcrowding in public health services and generate high costs due to prolonged hospitalizations and intensive treatments [Lessa *et al.*, 2023; Brazil, 2024; Medeiros, 2024]. To combat infectious diseases, a multidisciplinary effort is needed involving different professionals working in epidemiological surveillance, which corresponds to a set of actions that promote the detection, transmission, and prevention of diseases, as well as their risk factors. Epidemiological surveillance provides continuous technical guidance to health professionals, especially those working in health management [Albuquerque *et al.*, 2002].

With the advancement of digital health, systems based on the analysis and visualization of spatiotemporal data have helped health managers gain insights related to epidemiological surveillance, particularly in decision-making related to combating the spread of infectious diseases [Sopan *et al.*, 2012; Park *et al.*, 2022]. The availability of infectious dis-

ease data allows for a deeper understanding related to the formulation of prevention strategies and the management of epidemic outbreaks. Health managers need to be constantly prepared to analyze the visual representation of data to identify patterns and trends in infectious disease data. In this sense, serious and narrative games, combined with data visualization techniques, can assist future health professionals in developing skills and competencies related to epidemiological surveillance, allowing them to make data-driven decisions [Feitosa *et al.*, 2015; Dankbaar *et al.*, 2016; Borges *et al.*, 2022; Kejstova *et al.*, 2024; Ribeiro *et al.*, 2025].

Serious games are a type of game with a purpose beyond entertainment (education, training, simulation), using playfulness to achieve concrete objectives [Dörner *et al.*, 2016; Deguirmendjian *et al.*, 2016; Haoran *et al.*, 2019; dos Santos *et al.*, 2025]. The use of these types of games in health education can contribute to increased professional engagement, promoting significant and disruptive engagement compared to traditional teaching methods. Currently, serious games are applied in different areas of health, covering topics such as depression [Dias *et al.*, 2018], treatment of mild cognitive impairment [Jirayucharoensak *et al.*, 2019], mental health [Dewhirst *et al.*, 2022], and post-stroke rehabilitation [Mubin *et al.*, 2022].

Narrative-based games, on the other hand, focus on the player's experience of interacting with a storyline through textual immersion, where their choices shape the storyline and character development [Qin *et al.*, 2009; Dubbelman, 2016; Palomino and Isotani, 2024]. Narrative games combine an interactive storyline with decision-making elements that influence the unfolding of the storyline. In health education, this type of game can enhance engagement and facilitate learning by providing the player with the experience of living through different scenarios and consequences within an educational context [Dickey, 2006; Breien and Wasson, 2021; Neuwelt and Kearns, 2021; Ribeiro *et al.*, 2024].

Thus, the definition and modeling of the multiple objectives of serious narrative games are important in the teaching-learning process in health, as they can contribute to encouraging the intrinsic motivation to want to know more about a specific subject [Wang *et al.*, 2016; Rebah *et al.*, 2019]. However, the usability of these games must be taken into consideration, ensuring that ease of use and interaction are satisfactory for the user as the story unfolds. Thus, this specific type of game can truly aid in teaching concepts through a consistent narrative and the presentation of challenges throughout the entire gaming experience.

In this context, this study presents a serious narrative game prototype developed to assist in the training of undergraduate students in health management in combating the spread of infectious diseases. The game employs spatiotemporal data visualization techniques related to a problem-based scenario, based on real facts, with the aim of helping to identify patterns and trends and assisting in decision-making for the control of an infectious disease throughout the narrative. To define the problem situation, storyline, challenges, and usability of the game, we had the collaboration of a specialist in the area of public health, who acted as a stakeholder throughout the entire game design and development process, contributing to the adherence of the narrative to real management practices.

The narrative is based on a fictional intermunicipal health consortium, with four municipalities and their basic health units, their health professionals, and the characteristics of the population they serve. The player takes on the role of a health manager on their first day working at the intermunicipal health consortium and begins to understand the reality of the community, having to assist in decision-making related to planning the application of a limited stock of dengue vaccine. To aid in data presentation and decision-making, visual representations of spatiotemporal data and characteristics of the community served by the intermunicipal health consortium are presented.

The game was evaluated by seventeen students from an undergraduate health management program, who demonstrated acceptance and a favorable perception regarding its usability. The results indicate that the use of interactive narratives, combined with spatiotemporal data visualization, has the potential to support the training of skills and competencies for students in the field of health management, although this study did not assess the subjects' actual learning following interaction with the game.

The text is organized as follows. Section 2 discusses related work. Section 3 presents the adopted research method.

Section 4 presents the serious and narrative game proposed. The results of the usability evaluation of the game are discussed in Section 5, and the discussion regarding them is presented in Section 6. Finally, the study limitations and conclusions are presented in Sections 7 and 8, respectively.

2 Related Work

This section discusses some works related to this study, highlighting how serious and narrative games can effectively contribute to the various areas of activity of health professionals. These were selected from databases such as PubMed, IEEE, Scopus, Web of Science, and ScienceDirect, among others. Studies published in the last 10 years related to the topic of this research were filtered, considering the keywords: "serious games", "narrative games", "data visualization", "spatiotemporal data", "health management", and "infectious diseases".

The authors Dankbaar *et al.* [2016] present a study that focuses on evaluating the cognition and motivation of medical students by comparing traditional teaching methods with the interactivity and immersion provided by serious games. The results indicate greater participation and engagement of players in serious games compared to conventional approaches. In this game, the aim is to simulate training for medical students for emergencies based on the ABCDE of Trauma, which is a protocol to be followed for providing medical emergencies.

Zielke *et al.* [2016] state that the applicability of these games in areas of knowledge related to health is an aspect that contributes to the entire learning process of these professionals. The same authors explain that the skills of health professionals can be better explored and developed through serious games, and that such skills are essential for the daily practice of the profession, allowing them to provide better care, dedicate more attention to patients, and achieve more active and qualified listening.

In this context of teaching and learning centered on the use of serious games, the authors Bond *et al.* [2017], Diehl *et al.* [2017], and Haoran *et al.* [2019] reinforce the effectiveness and potential positive impact of serious games, not limited to the context of medical students, but extending to various professional areas in the health field. The study by Diehl *et al.* [2017], specifically, shows a serious game intended to empower medical professionals who are not specialists in Endocrinology, residing in the Southern region of Brazil. Bond *et al.* [2017], in turn, is based on interactive scenarios, consisting of questions and answers related to a specific antibiotic used in the treatment of serious infections caused by *Staphylococcus aureus*. In this game, for the player to progress, they need to answer the questions presented on each screen correctly.

The study by Tsopra *et al.* [2020] discusses the applicability of a serious game aimed at health science students, focusing on the administration of antibiotics to patients. The authors state that traditional teaching methodologies related to medication prescription in health science courses do not help students to better assimilate the content explored in the classroom, impacting their professional training. The authors further add that traditional teaching methods do not

focus on situations experienced in the daily lives of health professionals and state that classes can become tiring, not prioritizing the learning needs of each student, and may demotivate them.

Santos *et al.* [2022] present *Viral-izo*, a game-based learning approach designed to foster resource management skills against emerging viral attacks. The authors conducted evaluations using a metric for assessment of user experience, showing that *Viral-izo* is capable of educating while challenging the player. Derkasz *et al.* [2023] conducted a systematic mapping of serious games aimed at raising awareness about the *Aedes aegypti* vector and found that existing games focus on basic education, identifying professional training and higher education as significant research gaps. Palomino and Isotani [2024] provide a narrative gamification framework for educational environments, supporting the use of narrative structures as mechanisms for engagement and meaning-making in health education contexts.

Trindade *et al.* [2024] report on the development and evaluation of the serious game "*Francisca sem tempo para a Dengue!*" ("Francisca with no time for Dengue!"), which focuses on raising awareness about dengue, demonstrating that engagement mechanics and free web distribution can effectively reach technical education students. Additionally, dos Santos *et al.* [2025] present a survey of digital serious games in healthcare, indicating the consolidation of this research agenda within the Brazilian game community, while Menezes *et al.* [2025] discuss the use of serious games for health education and disease prevention in a broader context. In this context, de Vasconcellos *et al.* [2025] propose a preliminary model of sustainability, effectiveness, and equity to assess the suitability of game projects for use in public health policies, grounding the assessment in the principles of the Brazilian Unified Health System.

Regarding interactive data visualization as a support for public health, various authors have been publishing research with significant results. Araujo and Cedrim [2024] present *Arbolytics*, an interactive tool for monitoring arbovirus data that combines case notification statistics and spatial distribution using dengue and chikungunya data. Similarly, da Silva *et al.* [2025] present *DengueMG*, an interactive dashboard for monitoring dengue that utilizes epidemiological data, thematic maps, indicators, and simple charts to support public health surveillance. Although these systems do not address the use of serious games, they demonstrate the importance of interactive visualization, spatial aggregation, and temporal exploration in health surveillance contexts.

It is noted that different authors highlight the role of serious and narrative games in the training and development of professionals working in healthcare, promoting the generation of knowledge, the expansion of already acquired information, the acquisition of essential skills for the continuous development of systematic practice in healthcare, and the learning of leadership behaviors. The literature emphasizes the growing importance of games as an effective tool in assisting healthcare education, especially in the development of professionals from various fields. However, these studies also indicate a gap that the present work seeks to fill: the development of a serious and narrative game focused on the management of infectious diseases that utilizes interactive

data visualization techniques for the training of new health-care professionals.

3 Research Method

This research began with an identification, in the scientific literature, of research publications addressing the use of serious games for training in health management concepts related to the control of infectious diseases. Efforts were also made to identify related studies and technology-based solutions for health management regarding existing infectious diseases, to provide a foundation for this study. Furthermore, we conducted a systematic literature review on techniques for visualizing the spatiotemporal spread of infectious diseases [Oliveira *et al.*, 2025]. This analysis provided the basis for defining the visual representations of the data presented on the game dashboard and the interaction with them.

In addition, the game's narrative structure was defined based on concepts of decisions that would need to be made in proposed health surveillance actions. This initial stage made it possible to identify some initial requirements for the proposed game. However, to complement this, requirements were gathered from a professor who teaches in a higher education health management course and was part of the research team.

After gathering requirements, the game design and development began. A user-centered design approach [Kling, 1977] was adopted for this purpose, which places the user at the center of the design/project process, from conception to implementation of the game, aiming to understand the user's needs, desires, and behaviors. Throughout this process, the professor from the higher education course in health management, who assisted in the requirements gathering process, acted as a stakeholder, helping to balance the game's objective with usability for end users, drawing on their experience teaching public health policy.

For the development of the game's storyline, in addition to definitions based on the collected requirements, Syd Field's teachings on screenwriting were considered, along with aspects of the visual novel genre for digital games [Field, 2001]. This genre of games is based on creating a branching narrative, defining characters, settings, and decision points to structure the storylines. In this context, the events of the storyline are organized into chapters, focusing on avoiding excessive narrative complexity, as well as on integrating visual and sound elements to facilitate player engagement. The visual planning of the game's environments is also noteworthy, helping the player visualize the flow of the story and its different possibilities. These aspects contribute to the usability of the game.

For the creation of the game's artwork (scenarios and characters), we used generative artificial intelligence tools such as DALL-E [OpenAI, 2023] and MetaHuman [2026] for the character artwork. Focusing on rapid prototyping of the game as well as the presented dashboard, the Ren'Py [2026] engine and the Python programming language were chosen.

The prompts were developed iteratively by the team, with systematic human curation of the results to ensure ethnic and cultural representation appropriate for the Brazilian public health context. The generated images were reviewed

to mitigate representation biases typical of generative models, a particularly relevant aspect for an educational resource aimed at health management training. The development team holds authorship of the final images, having used these tools to support rapid prototyping. The use of generative artificial intelligence in this work was limited to generating images of scenarios and characters.

As the game was developed, a document called a short game design document [Motta and Junior, 2013] was created, which presents a complete description of the project, including mechanical and artistic aspects, and elucidates the requirements necessary for development.

After development was completed, the game was evaluated in relation to the usability presented as well as the suitability for use in the classroom. This evaluation took place with a class of the health surveillance discipline of an undergraduate course in health management, which constituted a non-probabilistic intentional sample. This class is taught by the professor who acted as a stakeholder in this research. The game's usability was evaluated in terms of effectiveness, efficiency, and satisfaction using a version of the System Usability Scale (SUS) method [Brooke *et al.*, 1996], with items adapted to the context of the proposed game. To complement the SUS, participants were asked to answer an open question, giving their opinion on the game. It is worth noting that, since the class consisted of 17 students, a sample of limited size, the confidence interval (CI) was used as an estimate of precision, employing Student's *t*-distribution.

The following sections present details of the project, development, and evaluation of the proposed digital game.

4 Serious Game based on Narrative and Data Visualization

This section presents the results from the design and development of the proposed game, detailing the execution of the steps mentioned in the previous section.

4.1 Requirements Gathering

The requirements identified through studies on the development of serious games for training in health management concepts related to infectious disease control, as well as data visualization techniques for this field, were complemented by the involvement of a stakeholder focused on developing attitudinal competencies in future health professionals. Using the user-centered design method, the stakeholder contributed to this requirements gathering phase as well as throughout the entire game design and development process. The requirements defined for this game were as follows:

- A serious narrative game, web-based to facilitate access and dissemination (online and free);
- A game focused on training the skills and abilities of students in undergraduate health management courses of their teaching-learning process, focusing on public health;
- Storyline and narrative related to combating and preventing a recurring infectious disease in the Brazilian public health scenario, including visualization techniques applied to spatiotemporal data;

- Planning of vaccination actions related to this disease, but with limitations similar to those found in real intermunicipal health consortium (IHC) and basic health units (BHU);
- The presence of characters representative of the real IHC scenario;
- Static scenarios, but representative of the narrated situations;
- Presentation of objective, multiple-choice questions related to key decisions that the player needs to make;
- Feedback at the end of the game indicating the correctness of the player's answers.
- The presence of usability ensures that the user interacts efficiently and effectively with the game and its dashboard, leading to satisfaction in using this tool to assist in their studies related to planning actions to combat the spread of infectious diseases.

Based on these requirements, characters, scenario, storyline, narrative, and game flow could then be developed.

4.2 Characters and Scenario

Within the context of the IHC defined for this game, the player takes on the role of a health manager who will assist in planning dengue vaccination campaigns. In addition to this role, four personas were planned, each representing a professional working in the IHC: family doctor, nurse, health surveillance agent, and intern/assistant. Figure 1 shows the game's initial screen with a graphical representation of these personas. The limited number of professionals represented in the game is intended to aid the narrative flow. Besides, the game was implemented in first person, and therefore, the player does not have an avatar.



Figure 1. Game characters that interact with the player.

The characters' appearances were defined by taking race and gender into account. Consequently, the characters reflect White, Black, Asian, and mixed-race backgrounds - including women in leadership roles within the narrative. This design choice aims to contribute to representation in educational technologies and interactive systems, ensuring a more inclusive user experience. The characterization of the five personas aims to create a multifaceted experience in the game by constructing realistic situations, enhancing immersion, and facilitating interaction throughout the presented script. It is also noteworthy that the four personas represent key functions in the daily professional life of the health manager character interpreted by the player, as each represents different

levels of experience and areas of expertise within the context of the proposed narrative.

To situate the game's narrative within a context close to the challenges of health management in Brazil, particularly involving public health policies, the main scenario was chosen to be an IHC, an association between municipalities for carrying out joint activities related to the promotion and protection of the health of their populations. IHC represents an entry point to the Unified Health System in the country, offering primary care services such as medical, nursing, and dental consultations, as well as health promotion and disease prevention actions, among others.

The proposed fictitious IHC serves four municipalities in the State of Rio Grande do Sul (Charqueadas, General Câmara, São Jerônimo, and Triunfo) (Figure 2) and their BHU (BHU and spatiotemporal data are also fictitious).

As for the infectious disease, dengue was chosen, which represents a challenging problem that has been growing in the tropical and subtropical areas of the country [Brazil, 2024; CEVS-RS, 2025].

4.3 Storyline and Narrative

With the characters defined, the storyline and narrative structure of the game were developed, considering the premise of presenting the main concepts about combating infectious diseases. However, these concepts needed to be addressed in a gameplay format, with challenges and rewards that would encourage the user to interact with the game. To this end, concepts of creative writing [Lee, 2019] and the hero's journey [Champagnat *et al.*, 2010] were employed in order to engage players and aid in their immersion in the proposed storyline.

The stages of the hero's journey were incorporated into the game's narrative structure as follows:

1. Call to adventure: The player's arrival at the IHC and the presentation of the epidemiological challenge by the narrator;
2. Meeting mentors and allies: The player interacts with the four professional characters (Dr. Ana, Nurse Jessica, the Agent, and the Intern), each providing essential information for decision-making;
3. Trials: The four multiple-choice questions regarding vaccination planning, supported by the interactive dashboard; and
4. Reward and return: Providing final feedback to the player on their performance regarding the questions, completing the learning cycle.

Considering the characteristics of narrative games based on the visual novel genre, the narrative is textual, presented with a focus on reading facts, aided by the player's immersion in static scenarios that accompany the story's evolution. However, unlike a book, the player actively participates in the story, making decisions that impact the unfolding of the plot, with dialogues adapted to the choices made. Thus, when the player makes the correct choice for a presented challenge, they receive positive feedback, confirming the correct answer and maintaining their number of lives within the game. On the other hand, when the player makes the wrong choice for a proposed challenge, they receive feedback indicating what the correct answer would be. In this way, players

have the opportunity to expand their skills and abilities in relation to the concepts presented, but playfully aligned with the proposal of serious games.

In this context, the game begins with the narrator presenting the context and dynamics of the game to the player. Next, the player is greeted by the character Ana, a family doctor who introduces herself, as can be seen below:

- [...]
- [Doctor] Hello. You must be [Player name], who came to collaborate with the strategic management carried out by our team. Welcome!
- [Doctor] I'll introduce you to our team, starting with me.
- [Doctor] I am the family doctor. I help with strategic planning for the management of infectious diseases in the communities where we work.
- [Doctor] My name is Ana. I hope you can help me with these new technologies.
- [Player] Nice to meet you, Dr. Ana.
- [...]

Next, nurse Jessica describes the characteristics of the IHC and the sociodemographic profile of the population they serve. Examples of these dialogues follow:

- [...]
- [Nurse] We serve approximately 90,000 people, of whom around 72,000 are already registered with IHC.
- [Nurse] People aged between 0 and 9 years old represent 13.3% of the registered population served, which is around 9,576 people.
- [Nurse] Young people aged 15 to 19 years represent 6.56% of the population, approximately 3,917 people.
- [Nurse] The largest age group is adults, corresponding to 30.23% of the population, around 21,774 people.
- [Nurse] The elderly population is composed of approximately 10,627 people, representing 14.76%.
- [Nurse] This is a middle-class region. The predominant level of education is high school, and the monthly income varies between 1 and 3 minimum wages.
- [Nurse] The main health problems are chronic diseases, such as hypertension and cardiovascular problems, mainly associated with obesity.
- [...]

In the sequence, the issue of dengue vaccination planning is addressed, indicating the target audience, the limited vaccine stock, and information about the epidemiological week are introduced by the health surveillance agent, as can be seen below:

- [...]
- [Agent] We've had a significant increase in dengue cases, as is common during this seasonal period.
- [Agent] Our goal is to define actions to mitigate this situation. We have three main challenges:
- [Agent] First: We have a limited quantity of vaccines, and we need to define which population to prioritize.
- [Agent] Second: We need to define which region to start the campaign in, as there are not enough vaccines for all regions.

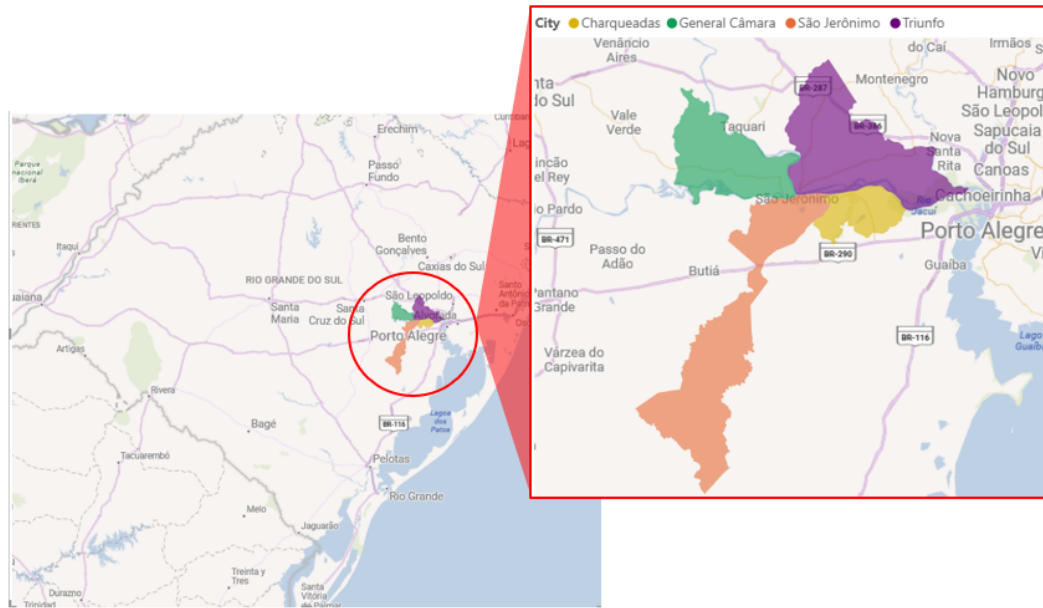


Figure 2. Cities in the state of Rio Grande do Sul are fictionally served by IHC of the game.

- [Agent] Third: We need to define the best date to start the vaccination campaign.
- [...]

The player then integrates into this scenario in the game, assuming the role of a health manager and assisting in decision-making regarding the vaccination campaign. Thus, after the last dialogue, the first multiple-choice question is presented to the player, with three possible answers, as shown in Figure 3.

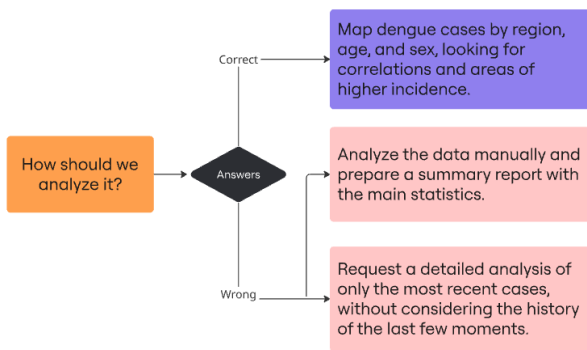


Figure 3. Question 1.

As the agent and the other professionals present the characteristics of the dengue vaccine, the player is invited to make strategic decisions by answering three interactive questions with multiple-choice answers (Figures 4, 5, and 6), only one of which is correct per question, as can be seen below:

- [...]
- [Agent] We received a limited quantity of the Qdenga vaccine.
- [Intern] Before we analyze the data, I have some questions about Qdenga.

- [Intern] Can we vaccinate people who have already had dengue fever?
- [Nurse] Yes, but it's necessary to wait six months after infection.
- [Intern] And what are the doses and the intervals between them?
- [Nurse] According to the package insert, Qdenga should be administered in two doses, with a three-month interval between them.
- [...]
- [Agent] Now that we have cleared up any doubts, let's move on to the challenges.
- [Narrator] You will use a dashboard with spatiotemporal data from the last 36 months relating to the four regions.
- [Agent] After analyzing the graphs, what age range do you suggest for the vaccination campaign?
- [...]

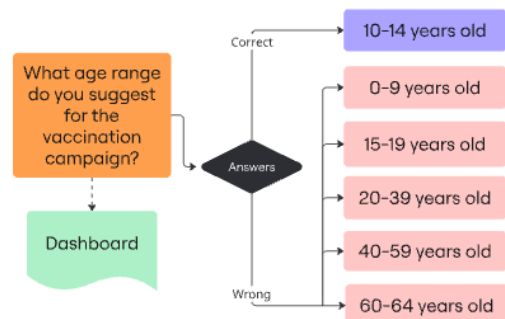


Figure 4. Question 2.

To aid in presenting the narrative and in solving Questions 2, 3, and 4, an interactive dashboard is provided during the game, displaying visual representations of spatiotemporal data related to dengue cases in the four cities served by IHC.

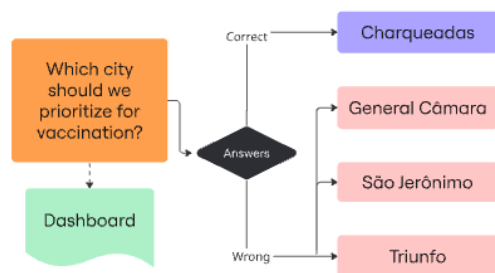


Figure 5. Question 3.

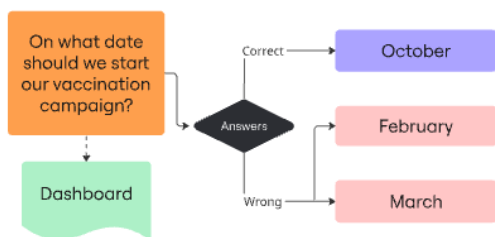


Figure 6. Question 4.

This dashboard aims to assist the player in making strategic decisions related to planning the vaccination of the population in these municipalities.

4.4 Game Flow

This section presents the flow of the developed game, describing how the dialogues, presented in the previous subsection, are connected to the sequence of events and interactions within the narrative, along with images and challenges. It covers everything from the player's introduction to the environment to the completion of objectives and the progression of the narrative. This flow was structured to keep players engaged and provide a fluid experience, with intuitive interaction and feedback related to the player's learning process. Thus, the aim is to ensure that the gameplay and usability of the game collaborate with the narrative, helping the player develop skills and competencies related to combating the spread of dengue fever. The complete game flow can be visualized in the flowchart shown in Figure 7.

In this Figure, rectangles preceding the questions present the theme addressed and the number of dialogues that are part of it. For example, the four rectangles before Question 1 (Figure 3) introduce the narrative, presenting characteristics of IHC, its team, the region served, and its population. Among these four initial rectangles, the first one introduces the game's context to the user, delivered by the narrator. This stage consists of seven dialogues that share the same scenario and are presented as the player clicks on the screen. Figure 8 presents the first dialogue in this introductory set.

The following dialogues mentioned in the other rectangles, before Question 1, are as follows:

- The player character's reception by Dr. Ana, the presentation of the IHC, the other professionals who work there, and the characteristics of the population served and their geographic regions (nine dialogues). Figures 9 and 10 showing the first dialogues of this group;
- The presentation of the problem related to planning the vaccination of this population against dengue fever, con-

sidering a limited number of vaccines and the date of the epidemiological week (sociodemographic profile) (twenty-five dialogues). Figure 11 shows the first dialogue of this group.

Then, Question 1 regarding the situation described by the agent is presented to the player (already mentioned in Figure 3) as can be seen in Figure 12.

Whenever a multiple-choice question is presented to the player, the number of "lives" they have in the game is represented by heart icons. The player starts the game with three "lives" and loses a life for each incorrect answer. Correct answers retain their lives. For each wrong answer, the player receives feedback on the correct concept. When all three lives are lost due to three wrong answers, the game ends. It is also worth noting that players are allowed to rewind moves during the game to review them and, if necessary, correct them, recovering lives. This design logic was chosen at the stakeholder's request to eliminate the frustration caused by excessive restrictions and focus 100% on training skills and competencies in health management related to combating the spread of infectious diseases.

Thus, the student's fear of failing in the game is replaced by a curiosity to understand "what happens if I do it differently?" Knowing they can backtrack, the player tests strategies and simulates the consequences of different choices, actions they would not attempt if the mistake were irreversible. This reflection on the causes and consequences of sound and flawed public health decisions is important for future administrators, who are constantly challenged by ever-changing infectious disease scenarios that demand decisive action.

Questions 2, 3, and 4 (Figures 4, 5, and 6), unlike Question 1, are supported by an interactive dashboard that applies spatiotemporal data visualization techniques. The next subsection provides details of this dashboard.

4.5 Data Visualization

To aid in the immersion in the storyline and narrative, a dashboard was designed consisting of five interactive visual representations of fictitious spatiotemporal data, defined to assist the user in analyzing fictitious spatiotemporal data related to the four municipalities and their situations related to dengue cases in the years 2022, 2023, and 2024, aiming to assist the player in making decisions regarding the prioritization planning of the dengue vaccination campaign in conjunction with the IHC proposed in the game. The synthetic data presented in the dashboard were calibrated using historical time series and national semiannual epidemiological bulletins [Brazil, 2024; CEVS-RS, 2025; SINAN, 2026]. The synthetic data for the four cities incorporate three fundamental patterns of Brazilian epidemiology: seasonality, age distribution, and urban-rural variation. This approach avoids training artifacts that could otherwise compromise algorithmic validity. These three patterns are detailed below:

- Seasonality, concentrating incidence peaks during the warmer, rainy months (October through May), with regional variations;
- Age distribution, prioritizing a higher absolute volume of cases among children and adolescents (the 10–14 age group); and

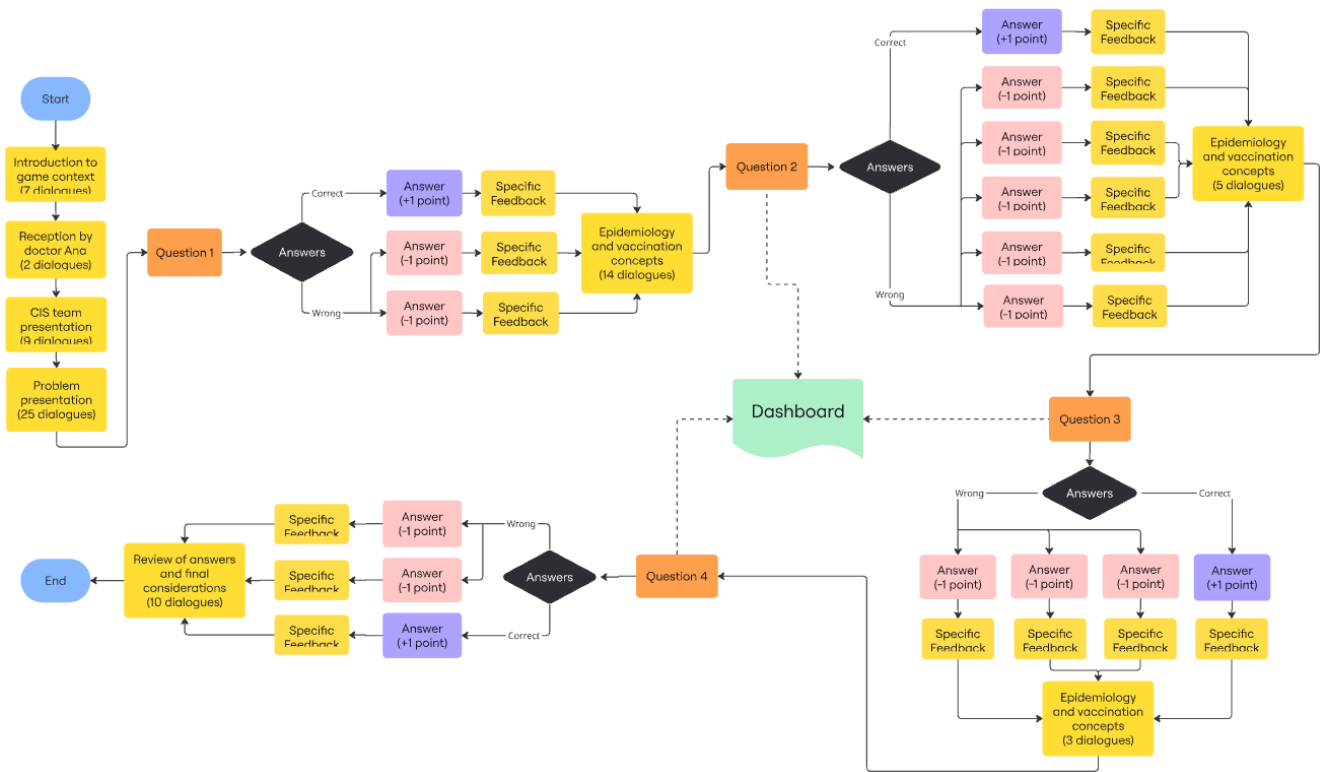


Figure 7. A flowchart of the player's interactions.



Figure 8. First introductory dialogue from the game narrator to the player.



Figure 9. Character Ana introducing herself to the player.

- Urban-rural variation, applying incidence coefficients proportional to local population density and sanitation infrastructure. This modeling ensures that the dispersal patterns of the vector *Aedes aegypti* reflect actual transmission dynamics in the country, minimizing causality biases and rendering the data suitable for robust model training.

Figure 13 presents an overview of this dashboard based on data visualization techniques. The following visual and interactive representations were used:

- Sunburst chart (Figure 14): used to present the total number of dengue cases in each of the four cities served by the IHC and their distribution between men and women;

- Treemap chart (Figure 15): used to display the number of dengue cases along with the number of hospitalizations and deaths in the years 2022, 2023, and 2024;
- Choropleth map (Figure 16): uses geographic areas filled with colors indicating the number of dengue cases for each of the four cities highlighted on the map of the State of Rio Grande do Sul;
- Line graph (Figure 17): aimed at visualizing the distribution of the total number of dengue cases throughout the months of the years 2022, 2023, and 2024;
- Grouped bars graph (Figure 18): aimed at visualizing the total number of dengue cases in comparison with the total number of hospitalizations and deaths, broken down by age group.

All charts on the dashboard are interactive, allowing the

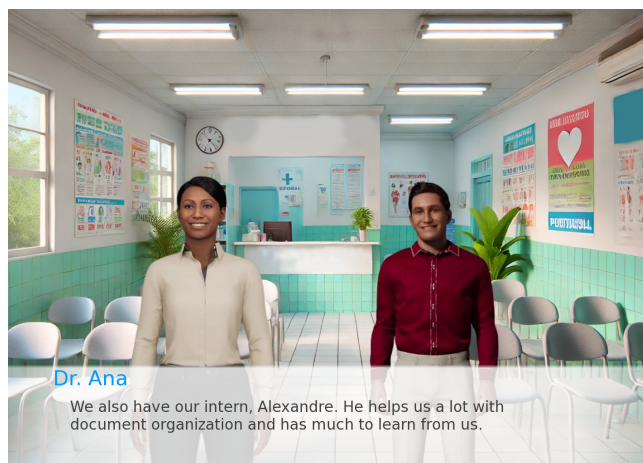


Figure 10. Character Ana, a family doctor, introducing Alexandre, an intern from the group of employees working at IHC.

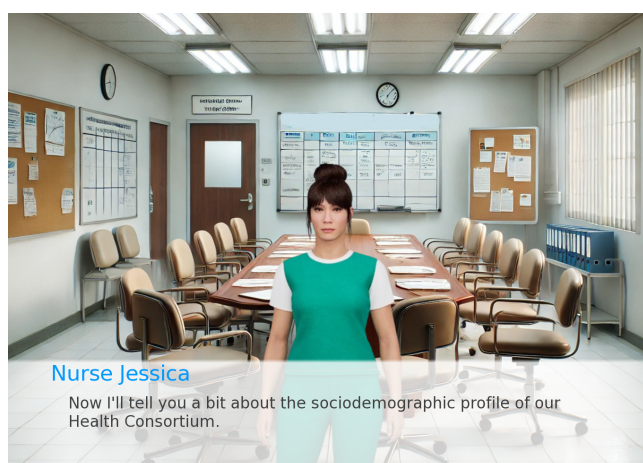


Figure 11. Character Jessica presenting the sociodemographic profile of the population served by the IHC.

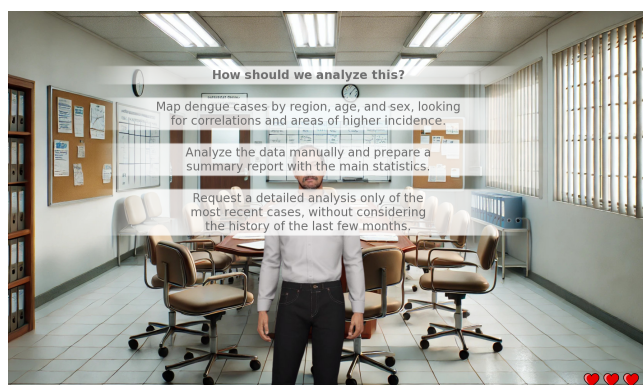


Figure 12. Character Agent presenting Question 1 and three possible answers.

user to filter and highlight data according to the desired analysis to aid in the decision-making process. When the player interacts with one chart, the others respond visually, adjusting to the applied filter as a system of multiple and coordinated visualizations. For example, to answer Question 3 (Figure 5) of the game ("Which city should we prioritize for vaccination?"), the player can consult the dashboard's choropleth map to identify the city with the highest number of dengue cases (Charqueadas, with 125 cases). In addition to

this information, the user can consult the grouped bar chart to determine the age group with the highest incidence of confirmed dengue cases (10 to 14 years old). With the age group identified, the player can click on the black bar corresponding to that group to verify whether the city with the highest number of confirmed dengue cases is also Charqueadas. Since that city has 34 confirmed cases, the player is expected to conclude that the correct answer to the question is "Charqueadas." The Figure 19 shows the dashboard with the charts adjusted based on this player interaction.

The next section presents information related to the usability evaluation of this game.

5 Usability Evaluation

Following the implementation of the proposed game, its usability and suitability were evaluated with a class of seventeen students (subjects) from a Health Surveillance course in a health management undergraduate program, taught by the stakeholder who contributed to this study. This course takes place in the third semester of the program (out of a total of nine semesters).

The subjects who agreed to participate in this study signed the informed consent form and served as users of the game (target audience), evaluating it for effectiveness, efficiency, and satisfaction. The 17 subjects were aged between 18 and 24, comprising 12 women and 6 men; all had prior experience with digital games, but only two had previous experience with interactive data dashboards. The topic of dengue vaccination policy had already been covered by the professor in class before this game usability test.

The project team presented the research objective, the game, and details of its operation to the subjects during a face-to-face class. Subjects were asked to explore the game freely, clarifying any doubts about its functioning with the proposing team. Subsequently, the subjects had a deadline to complete the experiment remotely, being able to interact with the game as many times as they deemed necessary and in their preferred location, provided they had internet access, since the game is accessed online. No personal data was collected from the subjects throughout the process. At the end of the experiment, participants were asked to complete the SUS questionnaire as well as an open-ended question regarding their feelings about the game.

The instrument underwent an adaptation process. The SUS scale items were adapted to the game's context by replacing the generic term "system" with terms related to health surveillance and specific to the game. Then, we highlight that this alters the scale's original psychometric construct, particularly because some items shifted from addressing personal intentions or preferences to focusing on general educational utility. This modification should be considered when interpreting the score obtained on the SUS scale.

The statements of which (Q1–Q10) are listed below:

- Q1) I believe this serious and narrative game can be used frequently in Health Surveillance classes.*
- Q2) I consider the game unnecessarily complex.*
- Q3) I consider the game easy to use.*
- Q4) I believe I would need help from someone with technical knowledge in epidemiological surveil-*

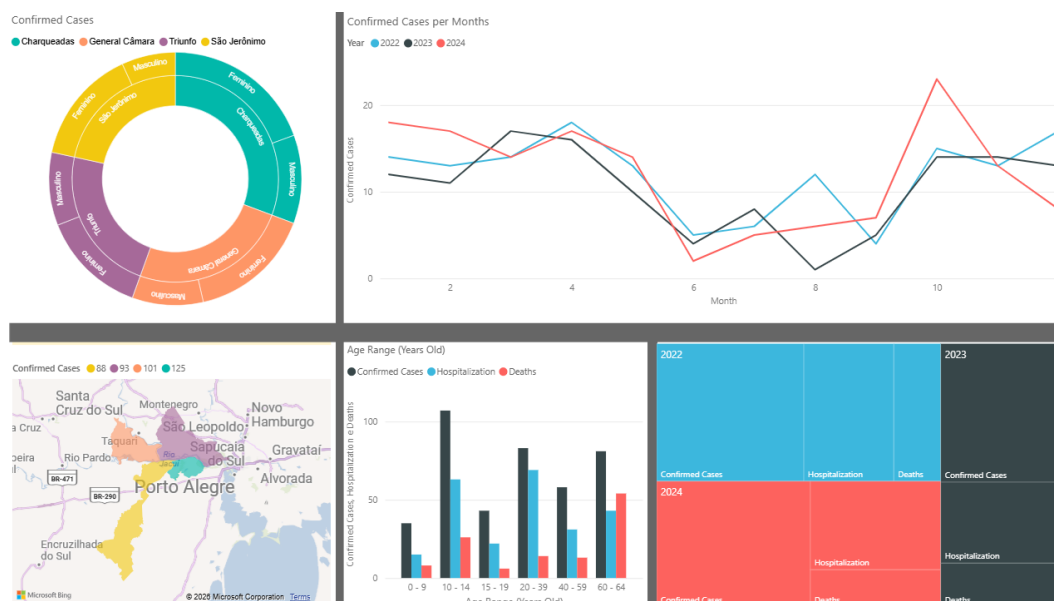


Figure 13. Dashboard of the game showing the spatiotemporal data visualizations.

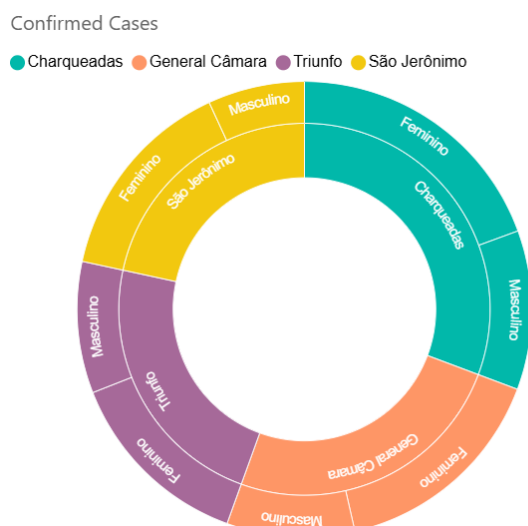


Figure 14. Sunburst chart.

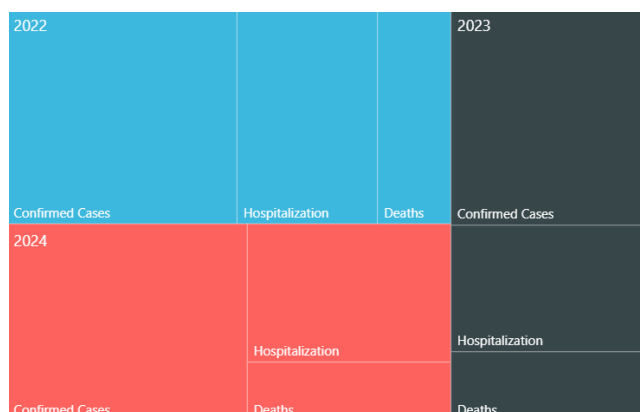


Figure 15. Treemap chart.

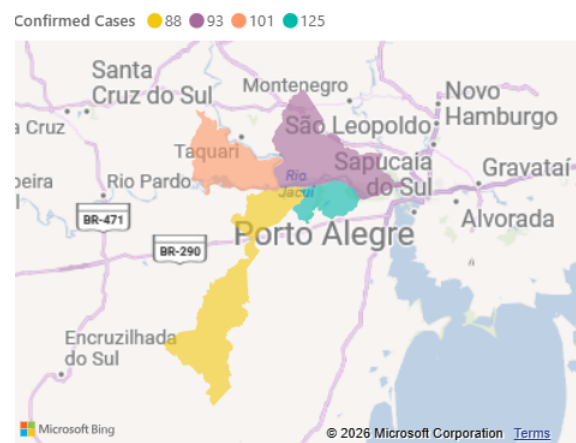


Figure 16. Choropleth map.

worked into the game and its dashboard.

Q6) I believe the game has many inconsistencies.

Q7) I believe people will learn how to use this game quickly.

Q8) I found the game confusing to use.

Q9) I felt confident using the game.

Q10) I needed to reinforce previously studied concepts to overcome the challenges presented by the game.

In SUS, each statement evaluation follows the Likert scale (ranging from 1 to 5): strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4), and strongly agree (5). It is noteworthy that odd-numbered statements (Q1, Q3, Q5, Q7, and Q9) are related to positive aspects of the game's usability, while even-numbered statements (Q2, Q4, Q6, Q8, and Q10) indicate negative aspects. Figure 20 presents the average student responses to each statement.

Considering the scores above 80% for the "Agree" and "Strongly agree" responses regarding the positive aspects presented in statements (Q1, Q3, Q5, Q7), it is noted that the majority of subjects who evaluated the game approved of its usability. This observation is corroborated by the fact that

lance to play the game.

Q5) I believe the concepts studied throughout the health surveillance course are well integrated and

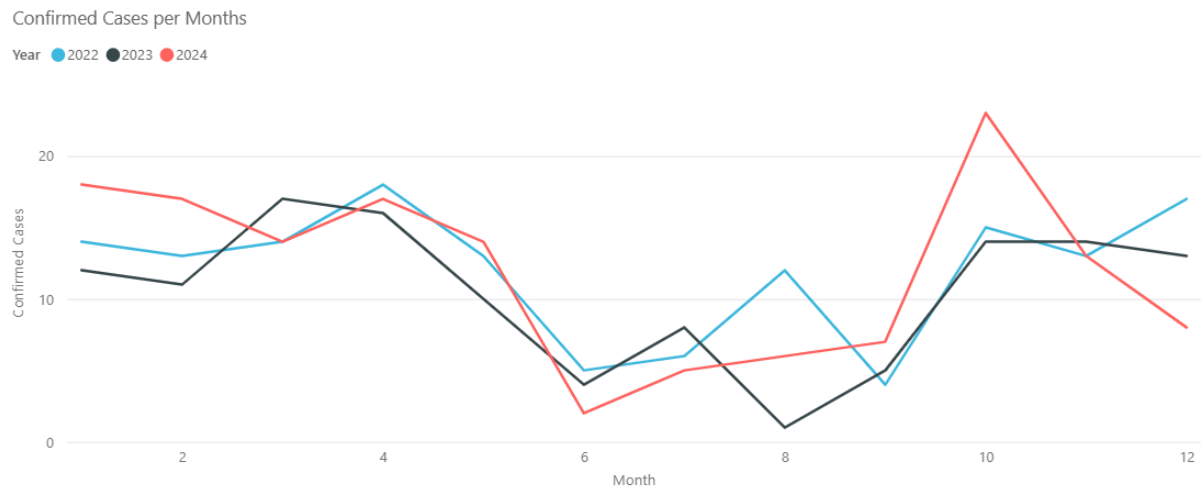


Figure 17. Lines graph.

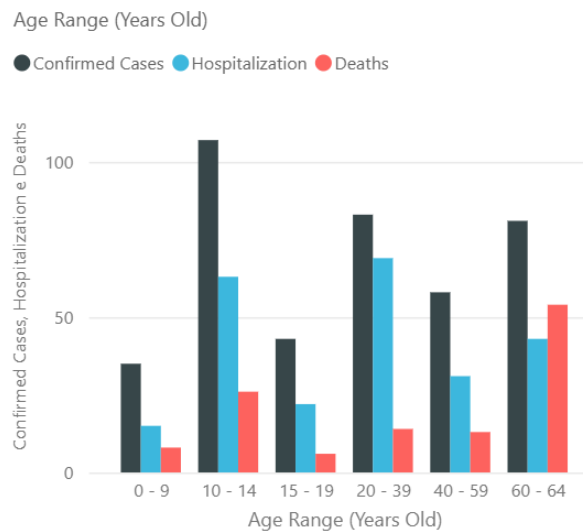


Figure 18. Grouped bars map.

the majority of responses to the negative statements (Q2, Q4, Q6, and Q8) showed around 75% disagreement ("Disagree" and "Strongly disagree"). However, it is worth noting that regarding statement Q9, 29% of users responded neutrally; this may be related to users experiencing difficulties, insecurity, or anxiety while playing the game, indicating a usability issue. Alternatively, it could also be linked to the need to reinforce the content covered in class regarding dengue vaccination planning. This hypothesis is reinforced when analyzing the percentage of responses to statement Q10, where 53% of the participants agreed with the need to reinforce previously studied concepts to overcome the challenges presented by the game, and 17.6% expressed a neutral stance regarding this statement.

Tables 1 and 2 summarize the SUS evaluation statistics and scores. Table 1, in addition to the ten SUS items, presents the following columns: "type" (indicating whether the item is positive or negative); "mean" (the arithmetic mean of the responses, where, in terms of usability, values closer to 5 are better for positive items and values closer to 1 are better for negative ones); and "SD" (the standard deviation of the response scores). Table 2 shows the SUS score per participant

and the total score (80.7). Note that SUS scores should be interpreted as follows:

- Above 80: Excellent usability (Grade A);
- Between 68 and 80: Good usability, but with room for improvement;
- Between 50 to 68: Below average; requires attention to prevent user attrition; and
- Below 50: Poor usability; urgent need for redesign.

Table 1. SUS statistics.

Item	Statement (abbreviated)	Type	Mean	SD
Q1	Use frequently in class	+	4.88	0.33
Q2	Unnecessarily complex	–	2.00	1.27
Q3	Easy to use	+	4.35	0.93
Q4	Needs technical help	–	2.00	1.17
Q5	Well integrated	+	4.71	0.69
Q6	Many inconsistencies	–	1.41	0.51
Q7	Learn quickly	+	4.65	0.70
Q8	Cumbersome to use	–	1.65	1.00
Q9	Felt confident	+	4.18	0.88
Q10	Needed to reinforce concepts	–	3.41	1.42

The medium score achieved in SUS was 80.7 with a SD of 8.8. According to benchmarks of Bangor *et al.* [2008], these obtained score corresponding to the classification "good/very good", over the historical average of the instrument (68), with the system generally demonstrating good performance in meeting user expectations.

The analysis of the items also reveals a consistent profile of approbation. The items with the greatest contributions were Q1 (desired frequency of use, mean = 4.88; SD = 0.33), Q5 (integration with the subject content, mean = 4.71; SD = 0.69) and Q7 (ease of learning, mean = 4.65; SD = 0.70). The low standard deviation in these three items indicates agreement among the participants. Negative items such as Q6 (inconsistencies) and Q8 (complexity of use) also show favorable results, with averages of 1.41 and 1.65, suggesting that



Figure 19. Dashboard display after the player selects the city of Charqueadas and checks the number of confirmed dengue cases in the 10–14 age group for that city.

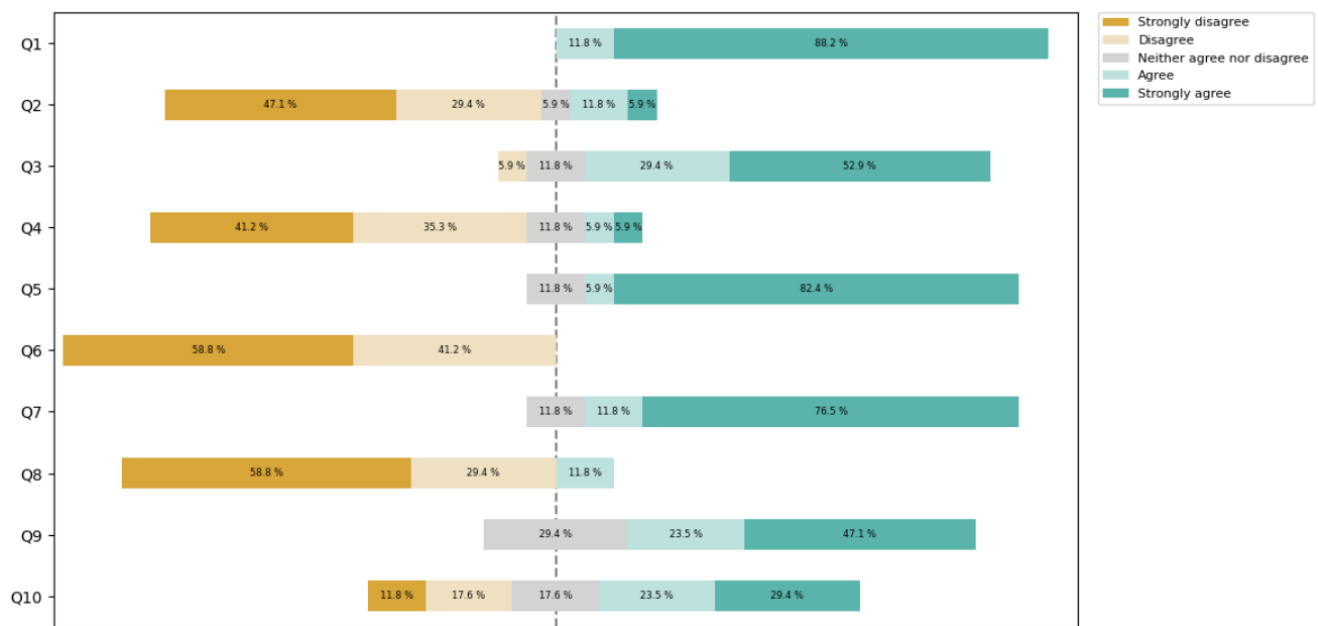


Figure 20. Percentages of subjects' responses to SUS statements.

the interface was perceived as consistent and relatively simple to operate.

Items Q9 and Q10 required the most attention. Item Q9 ("I felt confident using the game") showed 29% neutral responses, the highest rate among the positive items, suggesting that some participants did not feel entirely confident during the interaction, possibly due to the variable involving the analysis of spatiotemporal epidemiological data, given that only 12% of the subjects had prior experience using inter-

active dashboards. Q10 ("I needed to reinforce previously studied concepts to overcome the challenges presented by the game.") had the lowest contribution (mean = 3.41; SD = 1.42), with the highest standard deviation. This result reflects the heterogeneity in the subjects' prior preparation but is consistent with the game's training purpose, in which the player assumes the role of a health manager planning a dengue vaccination campaign amidst a vaccine shortage.

After the SUS evaluation, the following open-ended

Table 2. SUS score per participant.

Subjects	Individual SUS score
S1	72,5
S2	90,0
S3	85,0
S4	87,5
S5	85,0
S6	70,0
S7	77,5
S8	77,5
S9	92,5
S10	77,5
S11	60,0
S12	87,5
S13	87,5
S14	70,0
S15	82,5
S16	77,5
S17	90,0
Total SUS score: 80.7 (SD = 8.8)	

question was put to the subjects, who were free to choose whether or not to answer it: *"Would you like to provide comments, suggestions, and/or criticisms regarding the game being tested?"*. Of the 17 subjects, 8 responded (4 women and 4 men). Among them, 4 subjects expressed satisfaction with the game, highlighting it as a creative, dynamic, and interesting approach to epidemiological analysis, incorporating sociodemographic factors within the context of health management training for dengue vaccination planning. The game's flow, script, and scenario were also noted as positive elements that fostered player immersion in realistic situations. They further suggested that other topics covered in the Health Surveillance course should be considered for future versions of the game. However, 2 participants reported difficulty interpreting the dashboard data, indicating a need for further study on the subject. Additionally, 4 users suggested improvements, such as refining the feedback provided when a question is answered incorrectly. Finally, 1 subject emphasized the need to make the options for advancing and going back within the narrative clearer.

The next section presents a discussion of these results, including an analysis of the confidence interval for the usability evaluation results, given the small sample size of 17 participants.

6 Discussion

This research proposed the design and development of a serious, narrative game that, combined with spatiotemporal data visualization techniques, aimed to assist in the development of skills and competencies in health management for students. To this end, after identifying gaps and requirements through research in the relevant scientific literature and with the stakeholder, a fictional scenario was defined, involving an IHC, healthcare professionals working there, and related regions, seeking to simulate a scenario that could occur in the current Brazilian public health landscape regarding dengue vaccination. The representation of characters, based on different roles, sought to enhance the narrative in the healthcare

field, allowing players to connect with a healthcare environment that attempted to simulate reality, offering perspectives on the challenges faced by primary care teams in real life.

This game prototype was tested with a class from a health surveillance course designed to develop students' skills and competencies regarding the continuous monitoring of population health and the planning of measures to prevent and control serious diseases and risks. To assess the system's usability, a version of the standardized SUS questionnaire adapted for this game was used. The final sample consisted of 17 subjects, yielding a mean score of 80.7 points and a standard deviation of 8.8 points. To ensure the statistical rigor required for academic research, the data were subjected to a confidence interval calculation with a significance level of $\alpha = 0.05$ (95% confidence). Thus, the consistency of the responses is evidenced by the low standard deviation observed (8.8), a value lower than the average historical standard deviation for the SUS scale documented in the literature (approximately 12.5). This sample homogeneity lent mathematical precision to the interval; the lower limit obtained (76.18) lies above the average SUS score of 68 points, allowing for the rejection of hypotheses regarding low acceptability and scientifically validating the analyzed system as a product with good usability.

This indicates that the game's narrative approach, which presents an environment with challenges similar to the real-world experiences of health surveillance managers, offers good usability and has the potential to help students practice their skills in these situations, as intended. As highlighted by Lamprell and Braithwaite [2016], the characterization of health professionals in serious games, with a holistic approach, is fundamental for health promotion, as it allows players to engage in situations that portray paths of care and well-being. Through interactive narratives, these characters become effective instruments for sharing patient experiences, fostering empathy, awareness, and education on health topics. This strategy seeks to intensify the participants' emotional connection with the obstacles encountered, aiming to promote beneficial behavioral changes and a deeper understanding of the relevance of self-care and health management. Furthermore, Tori *et al.* [2022] explains that serious games effectively motivate students in health education, especially if there are characters linked to their area of interest with distinct characteristics, improving how these students will understand the dynamics of each character in the game.

Alongside the characters, the representation of a fictitious territory plays a strategic role, aiming to help the player exercise epidemiological reasoning, a key component in the management of infectious diseases, as suggested by Zielke *et al.* [2016] and Guo *et al.* [2021]. According to the same authors, the recreation of real scenarios, combined with the visual representation of territories, promotes problem-centered learning and encourages the generation of practical knowledge, particularly in complex contexts such as primary health care. This territorial context is essential for the player to understand the logic of the spatiotemporal data related to the spread of dengue fever, considering the different regions and their population profiles. According to the systematic review by Park *et al.* [2022], data visualization positively impacts decision-making in public health by facilitating interpreta-

tion and reducing the cognitive effort of users.

Data mapped to visual representations can be more easily interpreted, allowing for the identification of necessary actions in a given context. The authors Gabellieri *et al.* [2021] corroborate these points, highlighting the advantages of applying data visualization in healthcare, particularly dashboards as strategic tools for resource allocation and for identifying patterns in the spread of infectious diseases. This logic of action and consequence reinforces clinical reasoning and decisions focused on the epidemiological context, aligning with the proposal of serious games as decision-making simulators based on real data and practical applicability in health. As Silva and Santos [2023] argue, effective serious games are those that offer the player a space for reflection on the impacts of their choices, especially when these decisions are based on data and evidence.

These aspects were incorporated into the game, which was developed to reproduce elements of daily life in Brazilian public health, contributing to the player's immersion and situational awareness, and were evaluated in terms of usability using the SUS method, with users who constitute the potential target audience. Regarding the results presented, it is noteworthy that statement Q1, which addresses whether the game could be frequently used in the health surveillance discipline, statement Q5, regarding the integration of knowledge studied in the discipline within the game, and statement Q7, regarding the ease of learning how to use the game, have averages above 80%, demonstrating approval in terms of overall usability and integration.

Through this evaluation, it was possible to substantiate the resolutions regarding improvements in interaction with the game, in user assistance, and in the confirmation of usage criteria, which considerably assists in the constant improvement of the suggested platform. Interpreting these scores within the context of health challenges, user demographics, and specific system objectives ensures actionable insights for continuous improvement.

7 Limitations

The present study has limitations that must be considered when interpreting the results. The evaluation used a small sample ($n=17$); although sufficient for a preliminary usability test, the sample needs to be expanded to generalize the tool's effectiveness. Furthermore, the study does not include pre-tests and post-tests or control groups, a fact that precludes an assessment of actual learning following the use of the proposed game. Moreover, the sample belongs to the class of the professor who acted as a stakeholder in the development of the game, which may have introduced response bias in the SUS survey, since students could feel reluctant to evaluate negatively an artifact developed by their own instructor. To mitigate this risk, student participation in the game's usability evaluation was conducted remotely and without the presence of the involved teacher; furthermore, data collection was anonymous, and the professor had no access to individual responses, identifiable usage reports, or the identities of participating students, having access only to general, consolidated statistical data from the study at a later stage.

The SUS instrument was adapted to the context of the

game, which limits direct comparison with studies that used the original scale. The adaptation involved the SUS items; for example, the word "system" was replaced by "game". This adaptation was important to ensure participants responded to the items with greater accuracy by fully understanding them. Although the adaptation improved comprehension, it may have altered the instrument's original psychometric properties.

To conclude this section, the game is a prototype designed to address a specific problematic scenario: controlling the spread of dengue fever within an inter-municipal health consortium. As a prototype, it still lacks certain planned features and will be expanded to include broader decision-making opportunities, supported by evidence-based feedback, to enhance the player's experience.

Furthermore, the dashboard uses fictitious datasets, which limit comparisons with studies based on real-world data and may not fully represent the complexity and variability of actual epidemiological scenarios. Therefore, the findings should be interpreted as evidence of usability rather than evidence of realism or decision-making accuracy in real epidemiological scenarios.

8 Conclusion

The interaction and immersion provided by serious, narrative-based games can contribute to the creation of an innovative approach in the healthcare field, both in the classroom during the training of new healthcare managers and in the training of these professionals, since games have the potential to help improve their skills practically and dynamically. In the game presented in this study, the fictional territorial composition seeks to reproduce elements of the daily life of Brazilian public health, contributing to the immersion and situational recognition on the part of the player.

The representation of characters, based on different functions, aims to assist the health narrative, allowing players to connect with the health environment, offering perspectives on the challenges faced by teams in primary care. This narrative approach aims to aid in understanding the roles and responsibilities in the health sector. Besides, the interactive visualization of data seeks to help the player identify possible patterns and make decisions, simulating real-life situations that a healthcare manager may face in their professional life. This issue is particularly relevant considering that the present project aligns with the proposal of serious games as awareness and training tools, allowing the player to explore ethical dilemmas, care priorities, and strategies for the prevention and control of infectious diseases based on simulated data and real-life interactions.

In this enhancement, it is important to analyze the aspect of combining narrative, spatiotemporal data, and game decisions, which help in representing a realistic and challenging work environment. Thus, the game's dynamics aim to provide the player with an engaging and interactive experience. In doing so, it seeks to support the development of technical and operational skills and competencies in healthcare management by presenting problem-based decision-making challenges that simulate real-world situations faced by these pro-

professionals.

Regarding future work, we intend to expand the prototype to provide a more immersive experience, featuring more questions and challenges, as well as a more interactive narrative that offers the player greater autonomy. We also intend to apply a learning test to students and professionals focused on the management of infectious diseases in public health, as well as to develop other narrative versions, including other infectious diseases.

Declarations

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Authors' Contributions

- Gabriel Moraes de Oliveira is the main author of this manuscript, having participated in conceptualization, investigation, project administration, methodology, and writing.
- Elisangela Gisele do Carmo performed the investigation, writing, and text review.
- Raphael Maciel da Silva Caballero has contributed to conceptualization and validation.
- Isabel Cristina Siqueira da Silva was responsible for conceptualization, methodology, supervision, visualization, and writing.

All authors read and approved the final version of the manuscript.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

- Game link: <https://gamifyhealth.itch.io/epiviz-en>
- Adapted SUS questionnaire: <https://forms.gle/S717v5DxpKZxy5UGA>
- Research data files are available in the journal publication page: https://drive.google.com/drive/folders/1bTfmyP3tBv-ZQvKjbp9nuzuulKH-hq_D?usp=sharing

Further relevant information

Considering ethical issues, this study was approved by the Research Ethics Committee under the certificate of presentation of ethical assessment number CAAE: 83636024.5.0000.5345, having obtained opinion number 7.313.638. All stages followed the principles of resolution number 466/2012 of the National Health Council, ensuring the consent of the participants and the confidentiality of the information collected through the free and informed consent form.

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