

RESEARCH PAPER

ReqJourney: Engaging Students with a 2D Metaverse Serious Game for Software Requirements Education

Claudia Susie C. Rodrigues [Federal University of Rio de Janeiro | susie@cos.ufrj.br]

Thiago S. Nobre [Federal University of Rio de Janeiro | thiagosn@ic.ufrj.br]

Vitória Nazareth [Federal University of Rio de Janeiro | vitoriamna@dcc.ufrj.br]

Cláudia Werner [Federal University of Rio de Janeiro | werner@cos.ufrj.br]

✉ *System Engineering and Computer Science - COPPE/UFRJ, Av. Horácio Macedo, 2030, bloco I, sala 044a subsolo - Cidade Universitária, Rio de Janeiro, RJ, 21941-914, Brazil.*

Abstract. Teaching Software Requirements (SR) is a critical challenge in Software Engineering education, primarily due to the subject's theoretical nature and complexity, which often hampers student engagement. To address this, we developed and evaluated ReqJourney, a serious game implemented on the 2D metaverse platform Gather Town, designed to provide a dynamic, collaborative, and engaging learning experience for introductory SR topics, including requirements elicitation and analysis. An in-class evaluation was conducted with university students in a Software Processes course, utilizing the MEEGA+ model and pre/post-tests to assess educational effectiveness and user experience. The results demonstrate a significant improvement in student performance on the post-test and overwhelmingly positive feedback regarding the game's engaging mechanics and collaborative design. These findings underscore the potential of ReqJourney as an innovative educational tool, proving that combining immersive gameplay within virtual environments with structured learning objectives is an effective strategy for reinforcing complex SR concepts.

Keywords: Serious Games, Software Requirements, Software Engineering Education, 2D Metaverse, Gather Town, MEEGA+ Model

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1 Introduction

The discipline of Software Engineering (SE) is a fundamental pillar in technology courses, but its extensive and predominantly theoretical nature presents significant challenges in maintaining student engagement. Specifically, the sub-field of Requirements Engineering (RE) demands pedagogical methodologies that not only convey technical knowledge but also promote the development of social skills (Macedo *et al.* [2024]). To address these challenges, ReqJourney, a serious game that integrates gamified elements to make learning more dynamic and engaging, was developed.

This work is an extended version of the article presented at the III Workshop on User Interaction and Research in Game Development (III WIPLay), Brasília, Brazil (Rodrigues *et al.* [2024]). While the previous work focused on the initial conception and implementation of ReqJourney, the main objective of this article is to present a comprehensive evaluation of the game in a classroom setting, focusing on its educational effectiveness and user experience. The main contributions of this extended version include: (i) a detailed description of the in-classroom evaluation with 22 participants, (ii) an in-depth analysis of the results using the MEEGA+ model, and (iii) a discussion of the pedagogical implications of ReqJourney as an innovative tool for teaching Requirements Engineering.

The root of the problem seems to lie in the way SE is taught. In recent years, academia has devoted substantial effort to mitigating this issue by designing new approaches to teaching SE (Rodrigues *et al.* [2016]). To address these challenges, a serious game named ReqJourney was developed, designed to support RE instruction by integrating gamified

elements that make learning more dynamic and engaging.

Leveraging the potential of immersive technologies, ReqJourney was implemented on the Gather Town platform, a virtual environment that facilitates interaction among people. For a detailed description of the Gather Town platform and its functionalities, please refer to Section 2.1.

The game was divided into three exploratory and cooperative phases. Each phase addresses a specific topic, such as an introduction to SR, types of requirements, and requirements elicitation and analysis, simulating the natural interactions of a classroom and promoting collaborative learning. After the initial implementation, the impact of ReqJourney on learning was evaluated through a pilot test, which identified flaws and ambiguities in the game's dialogues and assessed the suitability of the gameplay duration for educational purposes.

After refinement, the game was evaluated in a Software Processes course, which covers introductory topics in RE. The evaluation involved 22 participants, organized in pairs, who went through a five-step process: a profile questionnaire, a pre-test, the experience with the gamified tool, a post-test, and an evaluation questionnaire. The pre- and post-tests, each composed of nine questions, were applied to measure students' knowledge before and after playing ReqJourney. Additionally, the evaluation questionnaire followed the Model for the Evaluation of Educational Games for Computing Education (MEEGA+) (Petri *et al.* [2019]), a methodology that ensures the game is both educational and engaging. The results of an in-class evaluation conducted with undergraduate students demonstrated a significant improvement in post-test scores compared to the pre-test, as well as high levels of satisfaction, engagement, and perceived learning based on the

MEEGA+ model. These findings support the effectiveness of ReqJourney in promoting an interactive and accessible approach to Software Requirements education. Therefore, the game presents itself as a promising tool to support teaching in immersive virtual environments.

This paper is structured as follows: Section 2 provides the theoretical foundation of the study. Section 3 presents and discusses the related works. Section 4 offers an overview of ReqJourney. Section 5 describes the design of the evaluation conducted. The findings, discussions, and considerations regarding threats to validity are outlined in Section 6. Finally, Section 7 concludes the work, summarizing the key insights obtained from the evaluation and outlining future steps and directions for the research.

2 Theoretical Foundation

2.1 Immersive Virtual Environment

Immersive Virtual Environments (IVEs) are computer-generated 3D spaces that simulate real or fictional scenarios, allowing users to interact naturally through technologies such as head-mounted displays. By engaging multiple senses, IVEs enhance users' sense of presence and immersion, supporting more effective learning and collaboration (Fernandes [2023]). Technological advancements have been transforming the educational landscape, particularly in higher education, through the use of emerging technologies aimed at improving teaching quality and meeting the demands of the digital world (Shwedeh [2024]). Among these innovations, the metaverse stands out for its ability to create IVEs that revolutionize teaching and learning processes. A metaverse is a three-dimensional, immersive digital world where users interact in real time with the environment and with others through their avatars, which serve as digital representations of the users (Pentangelo *et al.* [2024]).

The metaverse offers significant benefits for higher education, particularly by enhancing student engagement and improving learning outcomes. These virtual environments enable students to participate in simulations, engage in interactions, and collaborate with peers, creating a richer educational experience. This heightened engagement nurtures motivation, self-confidence, achievement, communication, collaboration, teamwork skills, and promotes self-directed learning. Furthermore, the immersive nature of the metaverse facilitates deeper learning and critical thinking, effectively preparing students for the challenges of the digital-era job market (Shwedeh [2024];Çelik and Baturay [2024]). By immersing themselves in interactive and dynamic learning environments within the metaverse, students can engage in role-playing activities and simulations that mimic real-world scenarios. This approach not only bolsters their understanding of complex concepts but also equips them with essential skills required in today's workforce, such as adaptability and problem-solving. However, the adoption of the metaverse in higher education also presents challenges, particularly concerning accessibility and adaptability. Not all students can access the necessary hardware and software to engage with the metaverse. Similarly, not all faculty members have the skills and knowledge to design and facilitate learning activities in this environment. Furthermore, the rapid pace of technological advancements in the metaverse

requires constant updates and infrastructure improvements, which can impose financial constraints on institutions with limited resources (Shwedeh [2024]).

Due to the realism with which the sensation of immersion is created in virtual environments, this type of virtual reality offers significant potential as an educational tool across various fields of knowledge. It enables the development of educational methods and experience-based learning by creating scenarios that visually emulate real-world environments. In these immersive settings, students can engage in tasks that enhance their understanding of academic content or gain insights that are challenging to acquire through traditional methods without direct experience. Moreover, there are now numerous versatile, user-friendly, and cost-effective IVR devices, making this technology increasingly accessible to educational institutions, including primary and secondary schools, as well as universities (Rodriguez-Florido *et al.* [2024]).

The Gather Town platform was chosen as a gamification tool for this project. The idea is to make learning activities more engaging for students, as an attractive visual appearance can enhance their motivation. Gather Town features pixelated graphics reminiscent of 1990s games, which appeal to users. It allows customization of characters' appearances and the decoration of spaces, such as specific rooms. These customizable decorations are diverse and functional, creating an environment where collaborative learning can thrive. According to Abusalim *et al.* [2024], applications utilizing the metaverse, such as Gather Town, provide students with a virtual space to interact and learn. Understanding how these platforms influence student motivation and engagement is essential, as this insight can help educators improve learning outcomes. Gather Town employs spatial audio technology, enabling students to communicate with each other based on the proximity of their avatars. This proximity-based video conferencing feature fosters social interactions that closely resemble real-life conversations in an informal setting, which are not possible with traditional, static video conferencing software such as Zoom, Google Meet, or Microsoft Teams (Zhao and McClure [2024]).

In this work, Gather Town was chosen for its ability to intuitively and accessibly bring people together in virtual environments. The platform not only allows the creation of multiple scenarios but also provides tools for the quick customization of objects in a visually stylized 2D environment. One of Gather Town's main advantages is its entirely web-based nature, requiring minimal resources and enabling anyone with a browser to access the game without difficulty.

2.2 Serious Games

Gamification, which applies game elements and mechanics in non-gaming contexts such as education, business, health, and marketing, is widely used to enhance engagement and motivation (Adams and Dormans [2012]). Craig *et al.* [2024] highlight that gamification in educational settings is an effective strategy for engaging students. In this context, serious games stand out as tools that enable the assimilation of content and the development of skills through playful experiences.

Ritterfeld *et al.* [2009] define serious games as games that, beyond entertainment, aim to achieve educational or simulation objectives. These games leverage interactive elements

from traditional games to teach or simulate real-world scenarios. When well-designed, serious games capture students' interest, enhance academic performance, and promote deeper, more engaging learning experiences. In this context, serious games emerge as an effective solution for simulating real-world scenarios and contexts, providing a meaningful learning experience. This approach is particularly advantageous in disciplines that are complex, extensive, and predominantly theoretical, such as SR. Here, the challenge lies in presenting highly technical concepts in a manner that is both accessible and engaging for students.

3 Related Works

This section presents and compares related works with the proposed project. The analyzed games are: GamES (Furtado *et al.* [2024]), NeuroSemio Game (Rampanelli *et al.* [2023]), Software City (Gomes *et al.* [2023]), Classifiqui (Monteiro *et al.* [2022]), Requirements Fiction Game (Corrêa and Xexéo [2024]), and a game that uses LEGO as an educational tool (Kurkovsky *et al.* [2019]).

GamES (Furtado *et al.* [2024]) is a serious game designed to promote greater student engagement in the SE course while reinforcing fundamental theoretical concepts. In the game, the player experiences a hypothetical “second software crisis” from the perspective of a software engineer, solving problems faced by themselves and their colleagues. There are several similarities between GamES and ReqJourney. Both games are structured in phases, each addressing a different topic of the target discipline. Their narratives also share a similar approach, placing the player in the role of someone working in the software field — although in ReqJourney, the player takes on the role of a beginner, allowing for a more gradual learning curve. Additionally, both games feature a 2D pixelated visual style, although GamES uses an isometric perspective. The main difference lies in the scope of content: while ReqJourney focuses exclusively on introductory topics in SR, GamES covers SE in a broader sense, with six phases, only the first of which is dedicated to SR.

NeuroSemio Game (Rampanelli *et al.* [2023]) is a serious quiz-based game aimed at teaching Neurological Semiotics. In this game, the player analyzes a patient's anamnesis and answers five questions related to the clinical case, with each case representing a level of the game. Despite being from a different field (Health), NeuroSemio Game shares with ReqJourney the pedagogical goal of reinforcing classroom content through a more engaging and interactive approach. However, the differences are considerable: NeuroSemio Game relies solely on a quiz mechanic, without the immersive exploration and narrative elements present in ReqJourney.

Software City (Gomes *et al.* [2023]) is an educational quiz game set in a 3D virtual world (metaverse), offering an alternative way to teach theoretical concepts in SE. In the game, the player explores the virtual environment and searches for computers that, when accessed, present SE-related questions. Similar to ReqJourney, players are encouraged to explore and interact with the environment. Both games share the same educational objective and include mechanics that allow player movement and interaction. However, Software City is built within a 3D metaverse, while ReqJourney is developed in a

2D metaverse, presenting a simpler graphical approach.

Classifiqui (Monteiro *et al.* [2022]), a serious game for teaching SE, was developed as a final undergraduate project at the Federal University of Ceará (UFC) in 2021. Like ReqJourney, its goal is to support learning in RE. However, while ReqJourney covers multiple introductory topics in the discipline, Classifiqui focuses exclusively on requirements analysis and classification, emphasizing the risks associated with incorrect categorization. In terms of technology, Classifiqui was developed using React Native and Firebase, requiring the full implementation of game functionalities. In contrast, ReqJourney leverages the built-in features of the Gather Town platform. Both projects were evaluated with university students who had already completed the RE course, although Classifiqui was tested with students from two different programs (SE and Information Systems). Both games received positive feedback in their respective evaluations.

The Requirements Fiction Game (RFG) (Corrêa and Xexéo [2024]) is a game based on Interactive Fiction, a genre in which player interaction occurs primarily through text commands. This feature marks a key difference from ReqJourney, which offers a visual and collaborative experience in a 2D environment. RFG focuses mainly on requirements elicitation and shares with ReqJourney the goal of making the learning of the discipline more engaging and motivating. Both games are set in a fictional company and place the player in the role of a requirements engineer. They also explore narrative immersion as a strategy to reinforce the understanding of key concepts in RE.

Kurkovsky *et al.* [2019] use LEGO as an educational tool to support the teaching of RE through two active learning modules. Unlike ReqJourney, which is fully digital and can be used both in-person and remotely, this game relies on face-to-face activities using physical blocks. One key difference is that in this game, the instructor acts as a stakeholder and provides the initial requirements for a “house” that students must build using LEGO bricks. This dynamic promotes reflection on communication, abstraction, and collaboration—skills that are also emphasized in ReqJourney. Despite their different approaches, both games reported improvements in students' understanding of the requirements process.

4 ReqJourney

ReqJourney is a serious game set in the 2D Metaverse of the online platform Gather Town. Its goal is to foster interaction among participants through their avatars, promote engagement in various virtual activities, and facilitate remote collaboration and communication to support learning in RE.

In the game ReqJourney (**Figure 1**), the scenario is described as follows: “You are the newest hire at a software development company called Techlândia. With no prior experience, you managed to land the job but now face the challenge of completing the task assigned by your boss: collecting SR for a client. Without sufficient knowledge, you must explore the various floors of the company, visiting different departments in search of tips and knowledge to help you accomplish your mission. Interact with more experienced employees to gain guidance. Each floor of the building represents a new phase and a distinct environment within the company. Face

challenges, learn, and grow along the way, becoming a competent professional in SR gathering." ReqJourney is played in pairs, promoting collaboration between participants. The pair wins by completing the task assigned by the boss. It is important to note that no numerical scores or grades were assigned to the tasks requested by the boss; progression in the game was determined solely by whether the task was successfully completed.

The game is designed as a serious game, meaning it serves an educational purpose. It supports the teaching of SR in an engaging and playful manner, appealing particularly to nostalgic players who enjoy 2D pixelated games. To enhance interaction and maintain player interest, it employs intuitive visual resources. The game is structured in phases with increasing levels of complexity, introducing foundational topics in SR within the context of SE. Collaboration is a key aspect, as the game leverages internet connectivity to promote cooperative learning. Additionally, it offers greater accessibility by requiring only widely available, less robust equipment. Finally, the gamified environment is designed to be expandable, allowing the inclusion of more advanced content for students who wish to delve deeper into the subject.

4.1 Game Mechanics

ReqJourney is structured into three main exploratory and collaborative phases, each designed to teach a fundamental topic of SR, integrating both theoretical and practical elements. Each phase unfolds on a different floor of a virtual company, where players must complete mandatory tasks to progress.

Player progression is guided by these tasks, and lobbies serve as checkpoints between phases. These lobbies offer opportunities for players to receive new instructions from their supervisor (NPC - Non-Playable Character), review their progress via in-game computers, and transition to the next stage through password-based challenges. Each lobby reflects the player's journey, updating with new content and interactions after every phase.

The game phases are structured as follows:

- Phase 1 – Administrative Sector: Introduction to SR, emphasizing their purpose and functional types. Players interact with NPCs like Joaquim and Josefa to gather initial knowledge and unlock the records room.
- Phase 2 – Human Resources Sector: Deepens the understanding of functional requirements and presents elicitation techniques. Players interact with Amelia for guidance and then engage in an interview simulation with a virtual character (Jéssica IA).
- Phase 3 – Development Sector: Focuses on requirements analysis, requiring players to collaborate to solve a final simulation involving prioritization, stakeholder communication, and validation of requirements.

Between these phases, specific lobbies play unique roles:

- Lobby 0 (Ground Floor): Serves as the game's entry point, introducing players to the virtual workspace and initiating their first mission.
- Lobby 1: Offers feedback from the supervisor and access to Phase 2 after completing Phase 1.

- Lobby 2: Prepares players for a structured client dialogue, setting the stage for requirement analysis in Phase 3.
- Lobby 3 (End of Game): Summarizes the learning experience, displaying a compiled log of acquired knowledge. Players assess their progress and unlock the rooftop celebration.

Throughout the game, players interact with highlighted objects (e.g., books, computers, documents, notes, doors, whiteboards) and NPCs. These elements provide essential clues and simulate a dynamic learning environment. The game's design allows players a degree of freedom to explore and complete tasks in various orders, except for the core missions that require password resolution to unlock the next stage.

4.2 Gameplay and Interface

The rules and mechanics of the game are as follows:

- The player can move in four directions (up, down, left, and right) using the arrow keys on the keyboard;
- Interaction with objects in the environment is done by pressing the 'X' key (configured by the platform);
- Objects are anything the player can interact with during the game. These will be accessed using the 'X' key and will be highlighted with a yellow outline to signal the possibility of interaction;
- Objects may include Books, Documents, Computers, Mini-games, Notes, Whiteboards, Doors, and NPCs;
- To unlock the elevator door, the player must find the clue that provides the password, which will advance the game to the next phase.

The game interface corresponds to the interface provided by the Gather Town platform. It is designed to be intuitive and interactive, combining visual and functional elements that facilitate navigation and interaction within the virtual environment. Here are the main components of the Gather Town interface:

- Overview: The main interface is a 2D map where users move as avatars through various layouts, rooms, objects, and decorations.
- Navigation: Players use the arrow keys or mouse to move their avatars around the map.
- Avatars: Users can customize their avatars with different appearances, clothing, and accessories. They can move freely around the map, interacting with objects and other avatars.
- Private Interaction Areas: Zones where only avatars within the area can see and hear each other, simulating private conversations.
- Interactive Objects: Items on the map that can be clicked to interact with, such as doors, documents, computers, and whiteboards.
- Video Calls: When avatars approach each other, their video and audio are automatically activated, enabling face-to-face conversations.
- Text Chat: A chat window where users can send text messages to the group or private messages to other users.



Figure 1. Characters interacting and communicating.

4.3 Development Setup and Platform Configuration

Before developing the final version of the game, a separate testing environment was created within the Gather Town platform. The goal was to explore core mechanics and familiarize the development team with the platform's tools and functionalities. This environment served as a sandbox for experimenting with essential features, such as password-protected doors, teleportation systems, and object interaction. These early tests helped guide key design decisions, such as structuring the game phases as different floors of a virtual company building.

In addition to the game's 2D pixelated aesthetic—which offers a nostalgic appeal for players who enjoy classic visual styles and contributes to an engaging and accessible experience—a major advantage of using Gather Town is its efficient performance on devices with modest hardware. This helps reduce costs and increases accessibility to a broader audience.

For use, it is recommended to access the platform through a modern web browser (such as Chrome or Firefox), with a stable internet connection and optional permissions for camera and microphone. The system runs on computers with at least 4 GB of RAM, an Intel i3 processor or equivalent, and Windows 10 Pro (version 21H2). The environment was tested on a desktop with the following specifications: Intel(R) Core(TM) i7-7700 CPU @ 3.60GHz, 8.0 GB RAM, NVidia GeForce GTX 1060 6GB graphics card, broadband internet connection, 1TB + 240GB storage (HD + SSD), generic headphones (optional), and a generic webcam (optional).

5 Evaluation

After developing the game prototype, it became necessary to evaluate the game. The MEEGA framework was adopted to assess whether the game effectively supports learning and provides a satisfactory user experience. The results of this evaluation offer insights into how the game can be used to enhance engagement and facilitate the learning process. The test was conducted in person in June 2024 across two laboratories of the Systems and Computing Program at COPPE, located at Federal University of Rio de Janeiro (UFRJ). Initially, a pilot test was conducted with two participants to validate the experimental protocol. These two participants were not included in the final evaluation. Therefore, the main study involved a total of 22 undergraduate students, all enrolled in the "Software



Figure 2. COPPE/UFRJ laboratory equipped with 14 microcomputers, used by students during the evaluation of ReqJourney.



Figure 3. COPPE/UFRJ laboratory equipped with 8 microcomputers, used by students during the evaluation of ReqJourney.

Processes" course. These participants had prior knowledge of SR and electronic games. **Figure 2** shows the laboratory equipped with 14 microcomputers, while **Figure 3** illustrates the laboratory with 8 microcomputers where the assessments took place.

5.1 MEEGA+ Technique

The MEEGA+ model (Petri *et al.* [2019]) was used to assess the educational effectiveness and user experience of ReqJourney. This model is specifically designed for evaluating serious games in computing education and is structured around multiple dimensions such as usability, motivation, satisfaction, and perceived learning.

In our study, the MEEGA+ model was applied through a standardized questionnaire, administered to participants immediately after their gameplay experience. The questionnaire consisted of Likert-scale items ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), covering all MEEGA+ dimensions. The results obtained from this questionnaire will be analyzed and discussed in detail in Section 6.1 of this paper.

Each item in the questionnaire was mapped to a spe-

cific MEEGA+ dimension, such as Aesthetics, Learnability, Operability, Accessibility, Challenge, Confidence, Fun, Satisfaction, Social Interaction, Focused Attention, Relevance, and Perception of Learning. Participants completed the EQ individually, and their responses were anonymized and aggregated for analysis.

The analysis of the responses provided insights into how players perceived the game's interface, its usability, the clarity of its rules, the level of immersion, and its relevance to their academic goals. These data were then used to guide the interpretation of the game's educational impact and identify areas for improvement in future iterations of ReqJourney.

5.2 Pilot Study

The pilot study was conducted once with two participants (a 22-year-old man and a 22-year-old woman) to validate the experimental protocol in person, identifying opportunities for improvement and mitigating potential threats to the validity of the results. Issues such as bugs, malfunctioning features in the scenarios, and player disorientation were the main problems observed.

For evaluation, the procedure would follow a predefined order: fill out the Consent Form, the Profile Form, complete the Pre-Test, play ReqJourney, complete the Post-Test, and fill out the Evaluation Form. All of these documents will be discussed later. However, the participants in the pilot test forgot or made mistakes regarding the order of the procedure, resulting in a total of three attempts (restarts) before correctly proceeding with the tests. As a method to mitigate this problem and collect the data properly, instead of letting the users access the document links themselves, they were properly opened and organized in the browsers before the main test began, so the users could just sit in front of the PC's and follow the tab's order.

Another issue was the participants' disorientation, as they often did not know how to progress in the game, which led the evaluators to give them hints to guide them. To prevent this from happening again in the main test, signs with a question mark symbol were placed throughout the scenarios to help players with the sequence of actions needed to progress in ReqJourney.

Additionally, malfunctioning of some features in the scenarios was pointed out by participants, such as typos in the dialogues with NPCs and the lack of interaction with certain items. Bugs were also identified and corrected from the pilot test to the main evaluation, such as objects and walls that players were able to walk through, leaving the scenario area. Suggestions for improvement from participants regarding the documents and other details were also taken into consideration when making adjustments to carry out an evaluation process that could produce more realistic results, reduce the evaluation time, and promote better collaboration among participants working in pairs. In this way, the evaluation went well, following the same procedure as the pilot test.

The pilot study used the following equipment configuration: Intel Core i7 7700 processor at 3.6 GHz, 8 GB of RAM, and NVidia GeForce GTX 1060 6GB graphics card.

5.3 Participants

The participant profile questionnaire gathered demographic data, assessed their previous experience with digital games, and captured their perception of their knowledge in SR. A total of 22 undergraduate students from the "Software Processes" course at the Institute of Computing, UFRJ, participated in the experiment, with 81.8% being male (18) and 18.2% female (4). 36.4% (8) were in the 5th semester, 27.3% (6) in the 4th, 13.6% (3) in the 2nd, 4.5% (1) in the 6th, 9.1% (2) in the 7th, and 9.1% (2) in the 8th semester. The average age was 21 years. Only one participant did not regularly play virtual games (the oldest, at 29 years old). The others frequently used computers (86.4%, 19 participants), mobile phones (54.5%, 12 participants), and consoles (36.4%, 8 participants) for gaming. Additionally, 63.6% (14) considered themselves experienced gamers. In terms of their knowledge of SR, 63.6% (14) were reasonably familiar with the topic, while 36.4% (8) had limited knowledge.

Although the profile questionnaire included a self-assessment item on participants' perceived knowledge of SR, the actual knowledge measurement was conducted through the Pre-Test Questionnaire, which consisted of objective questions aligned with the course content. The results of this test are discussed in Section 6.

5.4 Materials and Ethical Considerations

This section describes the materials used during the experimental study, conducted in person in two laboratory facilities, as mentioned earlier. The 22 devices had similar configurations with slight variations. The first laboratory had 14 (fourteen) microcomputers with Intel Core i5-7200U 2.50 GHz, 8 GB RAM, running Ubuntu GNU Grub 2.04, and Firefox Browser version 126.0.1. The second laboratory had eight (eight) microcomputers with Intel Core i7 3770S 3.10 GHz, 8 GB RAM, running Ubuntu GNU Grub 2.06, and Firefox Browser version 126.0.1.

Next, participants were provided with a printed Informed Consent Form, along with prior clarifications regarding potential risks associated with participation. These included the possibility of feeling tired, uncomfortable, embarrassed, or stressed. Participants were explicitly informed of their right to interrupt, resume later, or withdraw from the study at any time, without penalty. To protect data privacy, all collected information was anonymized and stored in a secure laboratory database accessible only to the lead researcher. After data collection and analysis, the digital data were permanently deleted, and all remaining information was transferred to a physical device under the sole responsibility of the research coordinator. To ensure traceability while maintaining participant anonymity and confidentiality, participants were identified only by numbers. Any publications or scientific dissemination resulting from this research will reference participants using numerical codes, preventing any possibility of identification and guaranteeing privacy.

Four questionnaires were developed and used throughout the experiment. The Participant Profile Questionnaire, whose results were presented in the previous section, was one of them. The Pre-Test Questionnaire (PT1) and Post-Test Questionnaire (PT2), both consisting of the same nine multiple-choice questions, aimed to evaluate the participants'

knowledge of SR content before and after interacting with the prototype.

The pre-test and post-test questions were designed to cover key concepts typically addressed in an introductory lecture on RE. The goal was to assess participants' prior knowledge and later evaluate how well they had internalized the content after engaging with the ReqJourney game. The questions encompass fundamental definitions (such as what SR and functional requirements are), essential processes (like requirements elicitation and analysis), and criteria used in requirements analysis, including business value, development effort, dependency, and urgency. The selection of questions was guided by the core topics that students are expected to understand after an initial exposure to the subject.

For the interaction with the prototype, participants had to access the game link so that two participants could be in the same 2D Metaverse environment and engage in conversation and idea exchange. Finally, the Evaluation Questionnaire (EQ) included questions designed using the MEEGA+ technique to assess the effectiveness and user experience in serious games.

According to Resolution 510/2016 of the Brazilian National Health Council (CNS), studies that collect only anonymous perceptions or feedback from participants, without identifying them or exposing them to risks greater than those encountered in everyday life, are exempt from submission and evaluation by the CEP/Conep system. This position aligns with internal procedures adopted at the Federal University of Rio de Janeiro (UFRJ), which recognizes that studies involving voluntary, non-invasive participation with anonymous responses and minimal risk do not require CEP approval. Nevertheless, all ethical standards for human-subject research were rigorously observed during the entire process.

6 Results

This section presents the results from the evaluation conducted during the use of the prototype. Participants verbalized their thoughts while exploring the environment. As a result, in addition to observing their interaction with the environment's features and behavior, it was possible to record the qualities and difficulties encountered.

Table 1 presents the scores of participants in the pre-test (PT1) and post-test (PT2), as well as the percentage of increase or decrease between PT1 and PT2. Out of a total of 9 questions, with the ninth question divided into five parts, the average score increased from PT1 to PT2. However, the first question, "What are Software Requirements?" dropped by 20%, and the third question, "What are functional requirements?" decreased by 6%. A possible reason for the decline in performance on Questions 1 ("What are software requirements?") and 3 ("What are functional requirements?") may be related to the highly theoretical and conceptual nature of these questions. Both questions presented response options that, although distinct, could generate doubts and confusion among participants, especially in an evaluation context. Additionally, it was observed that, due to the physical proximity between participants and their machines, and their organization in pairs, there were instances where oral communication was used to clarify doubts and advance in the game. At the moment of responding to the post-test, this interaction led to

the copying of answers among colleagues. Although the order of questions in the forms was randomized for each participant, with the aim of mitigating copying, students only realized this randomness after the start of the evaluation. This late discovery of the difference in question order may have contributed to the confusion and, consequently, to the unexpected drop in the percentage of correct answers for these specific questions, which were the first to be addressed by some participants. The other ten questions showed substantial increases in percentage (ranging from 5.1% to 61.6%). The largest increase was seen in the question: "Which of the following options represent good practices during an interview with a client?" with a 61.6% increase.

The comparison between the distribution graphs of pre-test (**Figure 4**) and post-test (**Figure 5**) scores shows a positive improvement in participant performance after the intervention. In the pre-test, the average score was 63.73, while the post-test average increased to 73.64. The central value (median) was 60 in the pre-test, rising to 80 in the post-test, indicating that most participants performed significantly better in the post-test. The range in the pre-test varied from 22 to 90, while in the post-test, it ranged from 26 to 90. Although the lower range shifted minimally, the concentration of higher scores reflects a better overall performance. Regarding the distribution of scores, the pre-test showed greater dispersion, with scores concentrated around 60-70, and few participants achieving maximum scores. In the post-test, there is a clearer concentration in the higher range (70-90), with noticeable peaks around 80. In conclusion, the post-test's shifted distribution to the right reinforces that the intervention (likely the use of the ReqJourney game) contributed to the learning and retention of content. The post-test graph demonstrates a significant improvement in participant performance, highlighting the positive impact of the applied methodology.

6.1 Usability Dimensions Analysis

To evaluate the user experience in ReqJourney, we analyzed the data using measures of central tendency—mean, median, and mode—for each usability dimension defined by the MEEGA+ model. While the mean provides a general overview of participants' responses, the median offers insight into the central value of the distribution, minimizing the influence of outliers. The mode, in turn, highlights the most frequently selected score. By including all three indicators, we aim to offer a more comprehensive understanding of how players perceived each dimension of the game, especially in the context of Likert-scale data, where relying solely on the mean can sometimes be misleading. This multifaceted approach allows for a balanced interpretation of the feedback collected. **Table 2** presents the results, with values ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The Usability dimension assesses the ease of use, navigation, and understanding of the game mechanics, as well as accessibility and user interface design (here, usability is subdivided into Aesthetics, Learnability, Operability and Accessibility).

Below is the analysis of these dimensions, according to Petri *et al.* [2019]:

- **Aesthetics:** This dimension evaluates the visual appeal of the game interface. Most participants rated aesthetics as "Strongly Agree," with both the median and mode

Table 1. Participant Scores in the Pre-Test (PT1) and Post-Test (PT2).

Question	% correct in PT1	% correct in PT2	% reduction	% increase
Question 1: What are software requirements?	90.9	72.7	20.0	
Question 2: Why do we need requirements?	77.3	90.9		17.6
Question 3: What are functional requirements?	77.3	72.7	6.0	
Question 4: What is requirements elicitation?	86.4	90.9		5.2
Question 5: Which of the following are possible techniques for eliciting requirements?	63.6	90.9		42.9
Question 6: Which of the following practices constitute good practices during a client interview?	9.1	95.5		61.6
Question 7: What is requirements analysis?	54.5	81.8		50.1
Question 8: Why is requirements analysis necessary?	45.5	50		9.9
Question 9a(*): The impact for the user measures how the software benefits or facilitates the lives of the end users.	81.8	90.9		11.1
Question 9b: Dependency identifies if a requirement is related to other requirements and needs to be implemented together.	90.9	95.5		5.1
Question 9c: Development effort estimates the time, resources, and skills necessary to implement the requirement.	77.3	86.4		11.8
Question 9d: Urgency determines the priority for implementing the requirement, considering its importance and the available time.	90.9	95.5		5.1
Question 9e: Business value evaluates how the software contributes to the organization’s strategic objectives.	72.7	86.4		18.8

(*) In Question 9, the participant must match each of the factors to be considered during requirements analysis with its corresponding description.

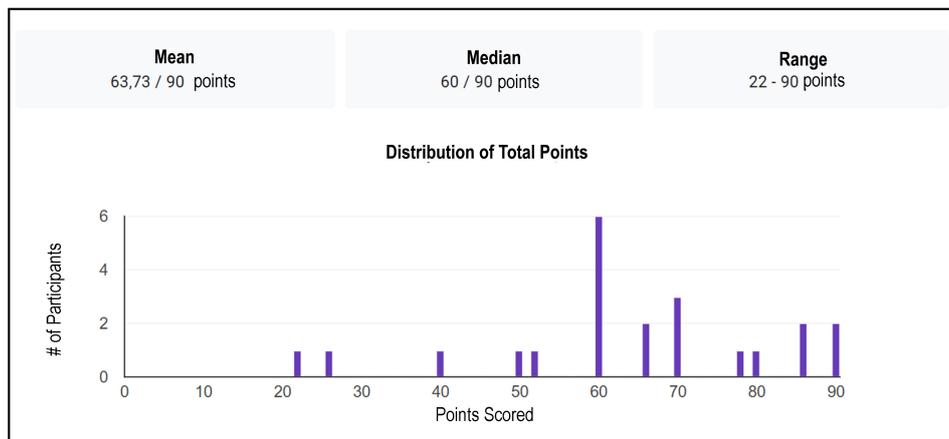


Figure 4. Distribution chart of total points scored by participants during the pre-test.

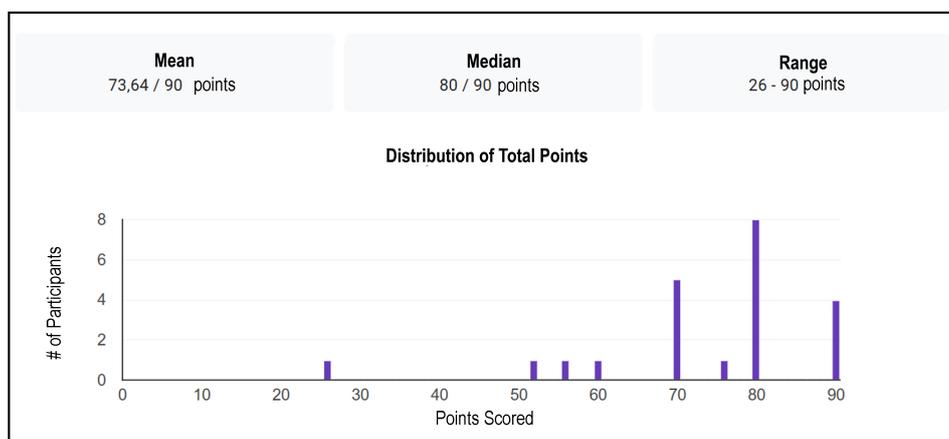


Figure 5. Distribution chart of total points scored by participants during the post-test.

Table 2. Central Tendency of Assessed Dimensions.

	Mean	Mode	Median
Aesthetics	4.55	5.00	5.00
Learnability	4.33	4.67	4.67
Operability	4.27	5.00	5.00
Accessibility	4.52	5.00	5.00
Confidence	4.45	5.00	5.00
Challenge	3.76	4.00	3.67
Satisfaction	4.22	4.75	4.75
Social Interaction	4.75	5.00	5.00
Fun	4.50	5.00	5.00
Focused Attention	4.24	4.67	4.67
Relevance	4.48	5.00	5.00
Perceived Learning	4.48	5.00	5.00

being 5, indicating high satisfaction. This suggests that players found the visual design to be attractive.

- **Learnability:** This dimension assesses how easily players can understand and navigate the game mechanics. The median and mode scores were both 4.67, reflecting a generally favorable perception among participants regarding the game's learnability. However, these results suggest there is still an opportunity to refine certain aspects of the mechanics for an even smoother player experience.
- **Operability:** This dimension, which evaluates the clarity of the rules and the ease of controlling the game, achieved a median score of 5.0 and a mode of 5.0. These results indicate that most players found the gameplay intuitive, with the mechanics being clear and accessible.
- **Accessibility:** This dimension received a strong evaluation, with both the median and mode at 5.0. These results reflect high satisfaction among players. However, specific tests are still needed to ensure the game is accessible to individuals with visual impairments, for example.
- **Confidence:** Confidence in the game as a teaching method was highly evaluated, with both the median and mode scoring 5.0. This demonstrates strong trust among participants in the game's effectiveness for facilitating learning.
- **Challenge:** The challenge dimension, which assesses the game's appropriate level of difficulty, achieved a median of 4.0 and a mode of 3.67. While the score suggests that the game was moderately challenging, it indicates that the difficulty could be adjusted by introducing more obstacles to further engage players and enhance the overall experience.
- **Satisfaction:** Player satisfaction, measured by the perception that their effort contributed to learning, received a high evaluation, with both the median and mode scoring 4.75. This indicates that most players felt highly satisfied, believing that the game effectively facilitated their learning experience.
- **Social Interaction:** Social interaction received a strong evaluation, with both the median and mode scoring 5.0, indicating that participants felt the game effectively fostered a collaborative and engaging environment. This high rating reflects the positive impact of the game in promoting teamwork and peer collaboration.

- **Fun:** The fun dimension received a top rating, with both the median and mode scoring 5.0, indicating that players found the game highly enjoyable and engaging. This result suggests that the game succeeded in maintaining player interest and providing an entertaining experience.
- **Focused Attention:** The focused attention dimension, which gauges the players' concentration and immersion, received both a median and mode of 4.67, indicating that the game was effective in maintaining the participants' attention and engagement throughout the experience. This suggests that the game successfully kept players immersed and concentrated on the tasks at hand.
- **Relevance:** The relevance dimension, which evaluates the players' perception of how the game content relates to their academic or professional goals, was highly rated, with both a median and mode of 5.0. This indicates that the participants perceived a strong connection between the game's content and their learning objectives, reinforcing its educational value.
- **Perception of Learning:** The perception of learning dimension, which measures how players feel the game contributed to their understanding of the SR subject, received both a median and mode of 5.0. This suggests that the participants strongly felt that the game was effective in enhancing their learning of the subject matter.

The overall results show a positive evaluation of the game, with high averages in all dimensions. The areas of aesthetics, social interaction, and fun were particularly well rated, while the challenge dimension showed a lower average, suggesting a potential area for improvement.

Two days after the evaluation of the ReqJourney game, a link was provided for participants to leave additional feedback. While optional, five students contributed. They unanimously praised the pixelated graphic style and the 2D format, stating that these elements made the experience more engaging and accessible. However, opinions on the cooperative aspect were mixed: some found the collaboration beneficial, while others reported difficulties in synchronizing with their partners.

Regarding the positive aspects, participants highlighted the easy gameplay, interaction, and design of the game, as well as moments of fun and laughter. As for the negative aspects, they mentioned issues with the password system and the lack of progress indicators within the game. Despite these points, all participants agreed that the game significantly contributed to learning RE, reinforcing the content in a fun and practical manner.

During the evaluation, several observations were made by the monitors. Some pairs of participants encountered difficulties advancing in Phase 3 and requested assistance from the monitor. However, many participants seemed to enjoy themselves and were actively engaged in the game. The collaboration within the pairs was key to their progress, as they motivated each other and explored the environment in search of secrets and clues. Some pairs took extensive notes throughout the game.

Participant 26, from pair 26/27, expressed great enthusiasm about the game, staying focused from start to finish. Additionally, one member of pair 7/8 complimented the retro/pixelated art style of ReqJourney. After the evaluation,

some participants left the following comments:

- "The game is really cool, congratulations, it was fun."
- "I loved it, very cool."

These comments reflect positive feedback, with participants appreciating both the enjoyment and the overall experience of the game.

6.2 Threats to Validity

Due to the synchronous format of the evaluation, certain aspects of its execution present potential threats to the validity of the experiment. One such threat is the homogeneous profile of the participants, as all students were from the same class, which may limit the generalizability of our findings. Additionally, participants worked in pairs and sat close to each other in the laboratory. Often, they did not use the chat feature, instead opting for oral communication to clarify doubts and advance in the game. At times, they even copied each other's answers, which raises concerns about the accuracy of the pre-test and post-test results in these instances. While the questions in the forms were randomly ordered for each participant to mitigate this issue, it cannot be guaranteed that responses were not copied. Furthermore, regarding the Limitations of Statistical Analysis, our study predominantly employed descriptive statistics (e.g., mean, median, percentage changes) to present the quantitative results obtained from the pre- and post-tests, as well as the MEEGA+ questionnaire. This approach was chosen in alignment with the primary objective of this study, which is of an exploratory nature and focused on evaluating the practical impact and perceived effectiveness of ReqJourney in a real classroom setting, rather than establishing broad statistical generalizations. We recognize that, while the observed results are indicative of the game's potential, they are not intended for rigorous statistical inference. Future studies, with larger and more diverse samples, will allow for the application of more advanced statistical methodologies to deepen the understanding of ReqJourney's effects.

6.3 Discussion

The positive outcomes observed in the post-test scores and the high ratings across MEEGA+ dimensions suggest that ReqJourney effectively enhanced student motivation, engagement, and understanding of foundational topics in SR. These results support the growing body of evidence that serious games, when well-structured and contextualized, can provide a more engaging and effective learning experience than traditional lectures alone.

Compared to other educational games, such as GamES (Furtado *et al.* [2024]), ReqJourney stands out for its immersive narrative and phase-based structure that simulates a professional software development environment. Unlike quiz-based tools like NeuroSemio Game (Rampanelli *et al.* [2023]), which rely solely on question-and-answer formats, ReqJourney promotes collaborative exploration, dialogue-based interactions with NPCs, and practical tasks. These features contributed to strong performance in dimensions such as Social Interaction and Focused Attention, demonstrating its potential to transform abstract SE concepts into meaningful, experiential learning. Furthermore, by using the browser-based 2D metaverse Gather Town, the game offers

high accessibility, even on low-end devices, and is particularly well-suited for remote or hybrid educational settings.

7 Conclusion

The use of the metaverse in education is becoming increasingly relevant, and ReqJourney shows great potential as an effective tool for teaching SR, enhancing students' attention retention without compromising the content. The game achieved satisfactory results, with extremely positive feedback from participants during an in-class evaluation. They highlighted the smoother learning experience and the ease of content retention, thanks to the game's interactive and gamified mechanics. These results emphasize the value of serious games in educational contexts, particularly in technical disciplines like Software Engineering.

7.1 Future Works

For future works, we plan to expand the ReqJourney game by adding new phases and content, as well as conducting a more comprehensive evaluation using the finalized version of the game.

To deepen the learning experience, the development of a fourth phase called "Requirements Modeling" is planned. In this phase, participants will navigate through an interactive maze where collaboration will be encouraged through the use of sequence diagrams. This immersive environment in Gather Town will allow players to explore fundamental concepts of modeling and diagrams, promoting active and collaborative learning.

Additionally, the content expansion will include more advanced topics, utilizing the structure and infrastructure already developed. There are also plans for improvements, such as incorporating more theoretical content in thematic spaces like the registry room or library, where participants can explore concepts in a self-directed manner. New interactive objects and NPCs will also be integrated into the game, enriching the narrative and increasing player immersion.

These innovations aim not only to diversify learning but also to make the game a more comprehensive and versatile tool for teaching Software Requirements Engineering.

Declarations

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Authors' Contributions

Claudia Susie C. Rodrigues contributed to the conception of this study. Thiago Nobre, Vitoria Nazareth, and Claudia Susie C. Rodrigues performed the experiments. Claudia Susie C. Rodrigues is the main contributor and writer of this manuscript. All authors read and approved the final manuscript.

Following the CRediT Taxonomy: Conceptualization: All authors; Methodology: Claudia Susie C. Rodrigues; Development:

Thiago Nobre and Vitoria Nazareth; Validation: Thiago Nobre, Vitoria Nazareth, and Claudia Susie C. Rodrigues; Formal Analysis: Claudia Susie C. Rodrigues. Investigation: All authors; Data Curation: Claudia Susie C. Rodrigues, Thiago Nobre, and Vitoria Nazareth; Writing – Original Draft Preparation: Claudia Susie C. Rodrigues and Cláudia Werner; Project Administration: Cláudia Werner; Funding Acquisition: Cláudia Werner.

Competing interests

The authors declare they have no competing interests.

Availability of data and materials

Datasets generated and/or analyzed during the current study are available in <https://lab3d.coppe.ufrj.br/reqjourneydata/> (Last access: 11 March 2026)

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