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Research Paper

Gamification Elements for Application in the Brazilian Navy Simulated Training Context

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Abstract. Although gamification presents the potential to increase engagement and motivation in learning environments, there are still gaps regarding the suitability of gamification elements for specific contexts, such as military training simulators. In this context, this study aims to identify which gamification elements are most appropriate for military training simulators, in order to contribute to the training process without compromising the fidelity of reality. This study also investigates the challenges related to the appropriation and perception of these elements in SiBART, a 3D military training simulator for combat vehicles. To achieve this objective, this research was carried out in different stages, including the identification of gamification elements in simulators according to the literature, the definition of the most attractive or relevant gamification elements according to the perception of military users, the redesign of the SiBART simulator, the use of gamified and non-gamified versions of the simulator by military personnel, with a counterbalanced order of use, and the collection of qualitative data through semi-structured interviews. The results indicate that the acceptance of gamification in the military context depends on the alignment of the proposed elements with the reality of training and with military values and practices. It was observed that gamification can contribute tactical challenges and time pressure aligned with military practice, with collaborative elements (such as gifting) that reflect companionship being well-accepted. In contrast, elements conflicting with doctrine (such as shops and individual rankings) may compromise fidelity. Finally, the perception and appropriation of gamification also depend on improvements in usability, visual integration, and system stability.

Keywords: Gamification, Military Training, Brazilian Navy, Training Fidelity.

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1 Introduction

The term gamification has attracted growing interest in both education and industry since it was introduced in 2003 Sera and Wheeler [2017]; Navarro [2013] due to studies pointing to the positive results [Hamari *et al*., 2014]. Gamification consists of the strategy of using game mechanics, dynamics, and elements in environments that are not necessarily games, aiming to motivate and engage people in the learning and problem-solving process [Kapp, 2012, p. 10]. Gamification emerges as a proposal to make the execution of activities or teaching/learning more attractive [Ribeiro *et al*., 2019], improve its users' performance [Silva *et al*., 2019], and improve student skill performance, bringing significant positive returns in the context of teaching/learning [Silva *et al*., 2015]. However, the benefit of gamification is directly related to the context of its application and the users who are or will be using it [Hamari *et al*., 2014], the context and the decision of which game elements will be applied are important factors for the success of gamified projects [Tong *et al*., 2016]. Nevertheless, it is not yet clear which gamification elements are most appropriate for each teaching context.

In parallel, simulators are defined as software that virtually replicate real-world situations or processes [Susi *et al*., 2007], allowing operators to be trained in diverse situations that are often impossible, rare, dangerous, or costly [Alves *et al*., 2010], such as in military training or surgical practices in medicine [Carvalho *et al*., 2013], offering a safe environment to make and correct mistakes [Alves *et al*., 2010].

In this context, instant feedback is important to support such training, acting as an immediate corrective mechanism. By allowing users to immediately perceive critical failures, the continuation of incorrect procedures is prevented, as noted by Stathakarou *et al*. [2024], who observed that instant feedback helped military personnel promptly recognize poor decision-making and general errors.

Some training simulators may have repetitive and/or mandatory activities, so gamifying them can make the repetition of their activities more enjoyable through playful elements and mechanics used in games, generating engagement and motivation so that their use is not merely out of obligation, and so that their users may want to perform the training in the best way possible [Kapp, 2012, pp. 10–12].

Despite several works having already pointed out the benefits linked to the use of gamification [Hamari *et al*., 2014], few training simulators utilize it for engagement and learning improvement. Among those that do, many do not clearly specify the game elements applied. Most of the analyzed works do not evaluate the impact of gamification [Chella *et al*., 2014; Batista *et al*., 2018; Brustolin and de Sá Brandão, 2017; de Amorim and Pellini, 2020; Amorim, 2023; da Silva *et al*., 2018]; some of them evaluate the simulation as a whole, without investigating the influence of gamification or specific elements. Moreover, for military simulations, Silva [2018] considers gamification to be for entertainment and without concern for reality, potentially harming the fidelity of military simulations.

These aspects motivated us to develop this work, that aimed to identify which gamification elements are most suitable for the context of navy training simulators, in such a way that they do not diminish fidelity and contribute to the training process. In addition, we investigated the challenges of appropriation and perception of gamification elements in a military training simulator. Therefore, to guide this investigation and achieve the objectives of this study, we formulated the Research Questions (RQs) below:

- **RQ1.** Which gamification elements are perceived as suitable in a military training simulator?
- **RQ2.** Which gamification elements are perceived as less suitable or reduce simulation fidelity in a military training simulator?
- **RQ3.** In what way do gamification elements contribute to the military training process?
- **RQ4.** What are the perception and appropriation challenges associated with gamification elements in a military training simulator?

We use the SiBART simulator [Dam *et al*., 2019], as a case study. It is a 3D naval battle simulation application for the Brazilian Navy's military training. It simulates real combat situations and aims to train soldiers in developing their skills for tactical responses and immediate reactions to different enemy attacks [Dam *et al*., 2019].

We conducted the following methodological research steps. Initially, we performed a literature review to identify studies applying gamification in simulators across various contexts, including military training simulators. Subsequently, we carried out an initial evaluation by applying a questionnaire to 20 military participants to identify the most engaging or relevant gamification elements for a military training simulator.

Based on the results, we selected phases (as complexity levels), time limits (as challenges), points/coins/badges (as a reward system), leaderboards (as a way to add competition), visual feedback, progress tracking, reward exchange for benefits, gifts (as cooperation), and voice chat (as communication) and include in a gamified version of the simulator, that we evaluated it with 16 military users, different from those who participated in the initial study.

We divided the participants into two groups. Each group used both versions of the simulator, with the order counterbalanced to control for order effects. After using each version, we conducted semi-structured interviews with each participant. Subsequently, we analyzed the interviews using the qualitative methodology of thematic analysis [Braun and Clarke, 2006].

We identified that users tend to receive well to gamification elements that are aligned with the reality of their training, their values, and their military practices. An onboarding process is also necessary, and all functionalities, whether gamified or not, should be visible to users.

1.1 Ethical issues

This research was conducted following ethical principles to ensure the protection and respect of the participants. All of them were informed about the study's objectives and procedures and signed a Free and Informed Consent Form before their voluntary participation for the user evaluation and interviews. To ensure confidentiality and anonymity, participants' data were coded, with students identified as A1, A2...A14 and instructors as I1 and I2 in the analysis and presentation of results. The interviews were recorded with due authorization, and the collected data were stored securely and used exclusively for the purposes of this research.

2 Contextualization and related work

Several studies [Ribeiro *et al*., 2019; Silva *et al*., 2015; da Silva *et al*., 2018; Batista *et al*., 2018; Chella *et al*., 2014; de Amorim and Pellini, 2020; Amorim, 2023] propose gamification or describe gamified simulators in areas such as health, support in teaching computer architecture, heritage education, programming education, and automation. Although many report a positive user perception, such as increased engagement and learning assistance, or an increase in usage time (interpreted as greater engagement by [Ribeiro *et al*., 2019]), few evaluate the application of gamification within their simulators. Frequently, their evaluations focus on their simulators as a whole, without distinguishing the contribution of gamification to the obtained results. Furthermore, a clear specification of which gamification elements were used and how they were selected is not always presented, hindering replicability and understanding of the mechanisms in action.

In the military context, Stathakarou *et al.* [2024] investigated the application of gamification in a Virtual Patient (VP) simulator for training Swedish military medics in trauma care. The study provides an assessment focused on user experience and concluded that gamification, along with the opportunity to make mistakes and receive immediate feedback in a risk-free environment, is a "*promising approach to military medical training*".

Brustolin and de Sá Brandão [2017] identified game elements in the *Brazilian Army's Cyber Operations Simulator* (SIMOC) and reported that students perceive the simulator as motivating and beneficial, mainly due to the freedom to make mistakes and its realism. However, the study did not evaluate how the identified game elements directly impacted the presented results.

In contrast, Silva [2018], when discussing improvements for the Brazilian Army's COMBATER simulator, position gamification as a potential "*bottleneck*", associating it with "*entertainment and lack of concern for reality*" [Silva, 2018, p. 11], which could compromise the simulation's fidelity. This view highlights an important tension: while many works see gamification as a positive additive, there is a concern about its suitability in scenarios that demand maximum realism.

The review of empirical studies on gamification conducted by Hamari *et al.* [2014] indicates that although gamification can have positive effects, these are dependent on the users and the applied context. The authors also point out several methodological weaknesses in existing studies.

This study aims to contribute to these gaps. Firstly, our study is situated within a little-explored context: simulator training in the Brazilian Navy. Secondly, this research conducted a comparative evaluation between a gamified and a non-gamified version of the simulator. This approach allowed us to investigate not only user interest but also the percep-

tion of the influence of specific game elements on training. The study sought to identify which game elements might be suitable (or unsuitable) for the military training context.

Finally, by analyzing user perceptions, we identified which gamification elements seem to work in the context of military training and how they are perceived, contributing to design indications for gamified military simulators that aim to balance them with training fidelity. Our focus is on investigating the challenges of the appropriation and perception of gaming elements in a training scenario that demands seriousness and alignment with operational reality.

Table 1 presents a comparative summary of related works, highlighting their limitations and how this research addressed those gaps.

3 Methodology

In this study, we used the SiBART Simulator, a 3D military training simulator for combat vehicles, as our case study [Dam *et al.*, 2019]. To achieve the objective of this research, we followed the steps below (Figure 1):

Firstly, we conducted a review to identify the gamification elements used in simulators in the literature. Subsequently, we performed an assessment through a survey to identify which gamification elements are most attractive and relevant to military users. Based on the results, we selected the gamification elements to be implemented in the SiBART simulator. Next, we redesigned the simulator by analyzing the inclusion of the selected elements and accordance with usability criteria. We then developed the gamified version and carried out an evaluation with military users, collecting data through semi-structured interviews. The data were analyzed using thematic analysis [Braun and Clarke, 2006], which led to the findings of this research.

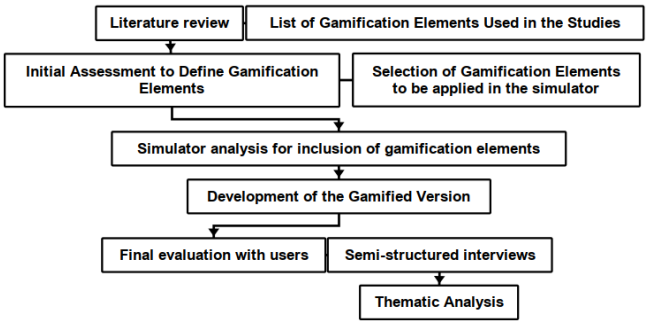

Figure 1. Diagram of methodological steps.

3.1 Case Study: Simulator SiBART

SiBART [Dam *et al.*, 2019] is a 3D military training simulator designed to train tactical response and immediate reactions to enemy attacks, simulating real combat scenarios that occur on a single terrain (Votuporanga-SP). During the simulation, participants in a vehicle face three types of enemies: two capable of inflicting damage (a 50 caliber shooter and an RPG) and one non-lethal (an aircraft) that tests decision-making. SiBART consists of two modules, a module for the instructor and other for the students (military personnel). A view of the student's screen is illustrated in Figure 2.

The students receive mission instructions to complete a route from point A to point B, with minimal damage and

Figure 2. View of the military interface during the simulation.

reacting correctly to enemy attacks. The instructor assigns roles as operator (moving the armored vehicle), commanders (handling the armored vehicle's weapons), and observers (unassigned students remain in the simulation only as spectators). According to the role assigned, the simulator shows in the screen a list of commands (Figure 3).

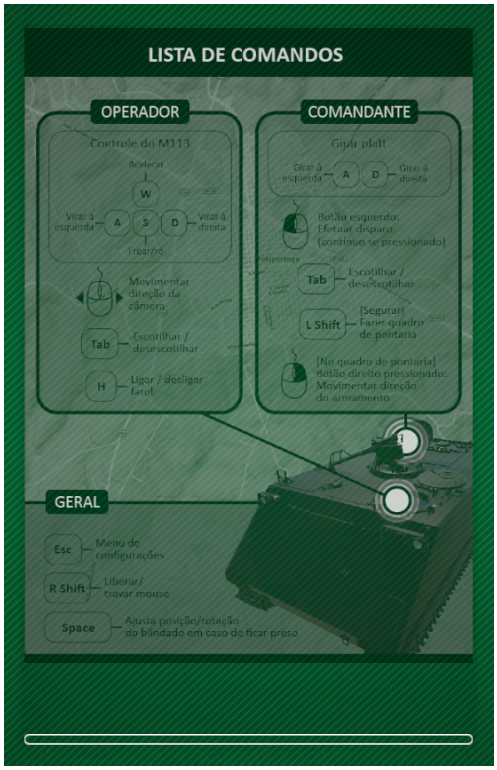

Figure 3. List of commands available in the simulation interface (original in Portuguese). The English translation is as follows. Operator (M113 Control): W/S: Accelerate/Brake or reverse; A/D: Turn left/Turn right; Mouse (horizontal): Move camera direction; Tab: Open/close hatch; H: Turn headlights on/off. Commander: A/D: Rotate platform left/right; Left mouse button: Fire (continuous if held); Tab: Open/close hatch; L Shift (Hold): Enter aiming mode; Right mouse button (Hold, while in aiming mode): Move weapon direction. General: Esc: Settings menu; R Shift: Unlock/lock mouse; Space: Adjust vehicle position/rotation in case it gets stuck.

The instructor configures environment parameters (date, time, and weather), monitors progress, and receives real-time feedback on events such as player connections, combat outcomes, and mission progress. Once the simulation begins, it runs continuously until completion, and the instructor can save session settings to be reused in the next simulation ses-

Table 1. Comparison between related works and the present research

Work and Context	**Approach**	**Limitation**	**This Study**
Brustolin and de Sá Brandão [2017] *Military (Cyber Attack and Defense)*	Identification of game elements in the SIMOC simulator and their influence on learning.	Evaluation of the simulator without investigating the impact of gamification on training.	Evaluates the impact of gamification on training.
Silva [2018] *Military (Military Doctrine)*	COMBATER simulator for training and doctrine validation.	Points to gamification as a risk to fidelity, but without investigating it.	Investigates the relationship between gamification and fidelity.
Stathakarou *et al*. [2024] *Military (Health/Trauma)*	Design of gamified Virtual Patients for combat trauma training.	Evaluated only the gamified version, without a comparison group using the non-gamified version.	Uses comparative evaluation (gamified vs. non-gamified version).
Ribeiro *et al*. [2019] *Health (Dental Anesthesia)*	- Motor skills and procedures training. - Application and evaluation of gamification.	- Lack of evaluation using interviews or open-ended questions to validate participants' opinions on the elements. - Outside the military context.	- Uses interviews to collect perceptions on each implemented element. - Military context.
Silva *et al*. [2015] *Health (Laparoscopic Surgery)*	- Motor skills and coordination training. - Evaluation of simulator usability and the applied gamification.	- Does not explicit the selection criteria for the applied gamification elements. - Outside the military context.	- Element selection based on an initial assessment with the users themselves. - Military context.
da Silva *et al*. [2018] *Education (Computer Architecture)*	Augmented Reality simulator (ARTEMIS) integrated into a textbook for teaching.	- Lack of evaluation of the simulator and the proposed gamification. - Does not explicit the selection criteria for the applied gamification elements. - Outside the military context.	- Performs evaluation of the gamification. - Element selection based on an initial assessment with the users themselves. - Military context.
Chella *et al*. [2014] *Education (Programming Teaching)*	Simulator for teaching algorithms through maze solving.	- Lack of evaluation of the simulator and the proposed gamification. - Does not explicit the selection criteria for the applied gamification elements. - Outside the military context.	- Performs evaluation of the gamification. - Element selection based on an initial assessment with the users themselves. - Military context.
Batista *et al*. [2018] *Education (Heritage)*	Development of a gamified Virtual Reality simulator for immersive experiences in heritage education.	- Lack of evaluation of the proposed gamification. - Does not explicit the selection criteria for the applied gamification elements. - Outside the military context.	- Performs evaluation of the applied gamification. - Element selection based on an initial assessment with the users themselves. - Military context.
de Amorim and Pellini [2020]; Amorim [2023] *Education (Industrial Automation)*	Virtual factory plant for gamified Hardware-in-the-Loop (HiL) simulations.	- Lack of evaluation. - Outside the military context.	- Performs evaluation of the gamification. - Military context.

Table 2. Gamification elements and evaluation in simulators in the literature

Simulator proposed in the studies	**Elements**	**Gamification Evaluation**
SIMOC [Brustolin and de Sá Brandão, 2017]	Narrative, Abstraction of concepts and Reality, Goals, Rules, Competition, conflict or Cooperation, Time, Reward structures, Feedback, Levels, Aesthetics and Replays.	Does not evaluate.
Dental Anesthesia Simulator [Ribeiro *et al.*, 2019]	Time, Levels, Error log, Icons, Ranking, Points and Trophy.	Evaluate.
LARG [Silva *et al.*, 2015]	Goals, Time, Reward Structure, Feedback, Levels, Replays, Ranking, Points and Sound Alerts.	Evaluate.
ARtEMIS [da Silva *et al.*, 2018]	Feedback, Levels and Points.	Does not evaluate
Virtual reality simulator for immersive gamified experiences applied to heritage education [Batista *et al.*, 2018]	Levels, Points and Trophy.	Does not evaluate.
Mobile robot simulator [Chella *et al.*, 2014]	Challenge, Competition or Cooperation and Reward Structures.	Does not evaluate.
COMBATER [Silva, 2018]	Not applicable	Not applicable.
Not applicable. [Hamari *et al.*, 2014]	Points, Leaderboards, Achievements/Badges, Levels, Story/Theme, Clear Objectives, Feedback, Rewards, Progression and Challenge	Not applicable.
Virtual Floor Plan of a Varnish Factory [de Amorim and Pellini, 2020; Amorim, 2023]	Progress Bar, Real-Time Control and Envolved UI	Does not evaluate.
Virtual patients (VPs) [Stathakarou *et al.*, 2024]	Points, Renovation, Feedback and Levels	Evaluate.

sion.

3.2 Literature review on gamification in simulators

To identify studies on gamification in training or educational simulators, we conducted a narrative literature review. Searches were performed using the Google Scholar academic search engine, Brazilian Computer Society's OpenLib and the Brazilian Army's Digital Library with the keywords "gamification" and "simulator". After the initial identification, the studies were filtered by analyzing their abstracts and introductions to confirm whether they addressed the application of gamification in simulators. For the selected works, we analyzed their objectives, evaluations, limitations, and results. This analysis allowed for the identification of the gamification elements employed in the identified simulators, which are listed in Table 2, indicating whether these elements were evaluated. Further details regarding them can be found in Table 1.

3.3 Initial user study

We conducted an initial study to identify the most attractive or relevant gamification elements for SiBART users, without relying on a specific gamification framework. We chose this approach so that the selected elements would be more aligned with the military users' preferences and perceptions, rather than being committed to a specific gamification structure.

Participants. We conducted the study with 20 male military participants (18 students and 2 instructors), aged between 20 and 35 years, from the Armored Vehicle School of CIASC (Admiral Sylvio de Camargo Instruction Center). These participants belonged to two programs: the Advanced Training Course and the Armored Vehicle Specialization Course.

Procedure and Data Collection. The procedure began with the participants performing a session in the non-gamified simulator. This session was preceded by instructions about the itinerary, commands, a map of the route, and a 5 minute familiarization period. The simulation, which was observed by the instructors, occurred in two sessions due to technical limitations.

After the session, the participants answered the questionnaires. For their elaboration, we used the elements listed in Table 2, which were the most applied in the studies analyzed during the literature review.

We applied questionnaires with distinct questions for each group. The students' questionnaire addressed their experience with games, familiarity with the concept of gamification, and their opinions on its application in the simulator, while the instructors' questionnaire focused on their perception of the gamification elements, the potential of these elements to contribute to the training, and the criteria for evaluating student performance.

Data Analysis and Selection of Gamification Elements. We analyzed the questionnaire results by examining the raw data and comparing related questions to identify patterns. The goal of this analysis was to understand what the responses indicated about each game element, assessing its suitability and the feasibility of its incorporation into the gamified version of the simulator.

Based on the analyzed data, we performed the selection of the elements to be implemented in SiBART. The selection was based on the combined results of the student questionnaires (identifying engaging elements) and the instructor ques-

tionnaires (assessing viability/relevance). After comparing the perceptions and identifying the convergences, we chose the most relevant elements for the gamified version, with the aim of contributing to the training process. The elements we included are described in Table 3.

Table 3. Gamification elements

Elements	Description
Phases	Addition of a new phase (diff complexity level).
Aircraft that causes damage	As a challenge in one of the stages.
Time Limit	As a challenge of one of the stages.
Rewards system	With the use of points, coins and medals.
Competition	Ranking of points and medals to generate competition among students.
Visual Feedback	Use of messages notifying and informing simulation events.
Progress	Showing the evolution of students' training in the simulator through the simulation history.
Exchange Rewards for Benefits/ Advantages	With the possibility of exchanging coins earned during the simulation for items that can be used as aid during training.
Gifts/Cooperation	Enabling students to give items as gifts.
Communication	Using the Voice Chat

3.4 Redesign and development of the gamified version of the SiBART Simulator

After selecting the gamification elements, we conducted a detailed study of the simulation to determine how and where to insert them. In this redesign phase, besides the introduction of gamification elements, we considered the implementation of usability improvements identified in the work of [Zilberberg, 2019].

3.4.1 Gamification Elements

We describe below the gamification elements that we have implemented in the new version of the simulator.

Phase 2. We added a new independent phase (selectable by the instructor) with updated challenges/obstacles: An aerial enemy that causes damage and a time limit (selectable by the instructor) for completing the simulation.

Reward System (Points, Coins, and Medals). To praise students' actions during simulations and motivate them to perform the training in the best possible way, the simulator grants points and coins for certain actions, such as escaping from or eliminating an enemy (Figure 4). Additionally, instructors can evaluate subjective criteria (e.g., communication and individual/group performance) and award medals and feedback messages at the end of the simulation (Figure 5).

Ranking (Competition). A new ranking screen displays the students' classification (by points or medals) with the objective of encouraging competition (Figure 6).

Figure 4. Message displayed when the student collaborates with the neutralization of the enemy with a .50 caliber weapon (Gamified) (original in Portuguese). The English translation of the central message is: "The .50 enemy is no longer a threat. You earned 1 point(s) and 10 coin(s) for collaborating with your team".

Figure 5. Medals and Comments (Gamified).

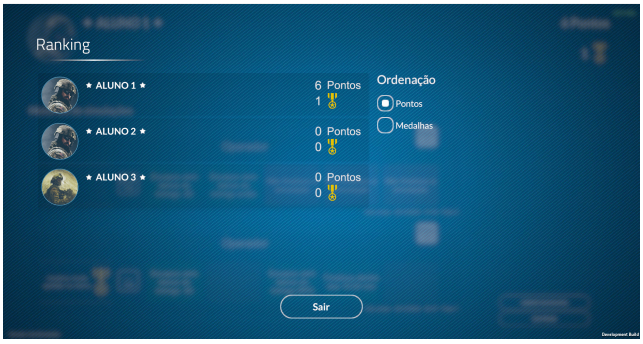

Figure 6. Ranking (Gamified).

Visual Feedback. We enhanced the feedback to keep students and instructors aware of events, providing information about points earned, causes of death, enemy status, proximity to the objective, and simulation completion (Figures 4 and 7), replacing the previous generic messages so they can be aware of simulation events.

Student Menu and Progress. In the non-gamified version, after the login screen, students were directed to a waiting screen until the simulation started. For the gamified version, we created a new student menu screen (Figure 8), which centralizes general data (avatar, points, coins, medals) and a detailed simulation history (simulation settings, role, rewards, obstacle status). The objective is to allow the student to monitor their progress and compare their performance over time.

Figure 7. Simulation time is ending. (Gamified) (original in Portuguese). The English translation of the central message is: "30 seconds remaining until the end of the simulation!".

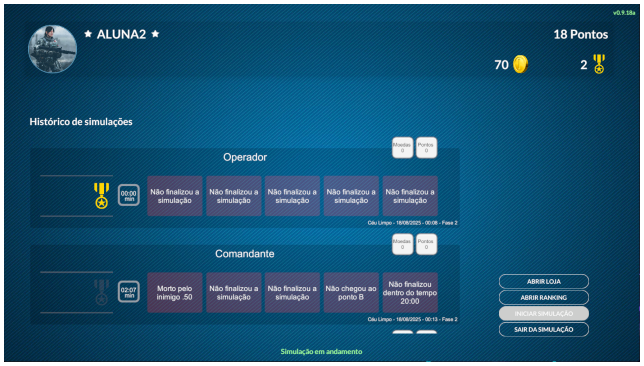

Figure 8. Student menu indicating simulation in progress (Gamified).

Store (Exchange for Items). We added a store (Figure 9), accessible from the student menu or "Left Ctrl" which allows exchanging coins for benefits/advantages, which are single-use items (e.g., speedometer). To maintain realism, we used the same items that the instructor could already configure in the non-gamified version.

Gifts (Cooperation). To encourage cooperation, students can buy any item (even if it is not for their role) and gift it to a colleague (Figures 9). This allows them to help each other if someone does not have enough coins, benefiting the team.

Voice Chat (Social Interaction). We implemented a voice chat to improve social interaction and collaboration among students, something also suggested by [Zilberberg, 2019].

Instructor Resources. In the instructor environment, it is now possible to select the new phase and its duration in the simulation configuration tab. They also have access to the ranking and individual history of students to gain insights into their progress (Figure 10).

Figure 9. Store (Gamified).

Figure 10. Student simulation history screen (Gamified).

3.4.2 *Usability improvements*

We also considered some usability improvements based on the suggestions of [Zilberberg, 2019], who performed an inspection evaluation (heuristic analysis) of the simulator. From this analysis, the author identified interaction problems and suggested solutions aimed at a better user experience. We used the suggestions applicable to the new version of the gamified simulator. We detail these changes in Tables 4 and 5.

Additionally, with the aim of improving the simulator's usability, we also considered some other changes. For the initial screen, where the user must choose between the two different environments (Student and Instructor), the options "Client" and "Server" were updated to "Student" and "Instructor" to facilitate environment identification. For the student environment, the text size of the feedback messages shown to them during their simulation can be customized, with the option to choose between three different sizes (Figure 11), allowing them to select the most comfortable size that does not obstruct their view. For the instructor environment, we added numerical IDs to the armored vehicles shown on the map (Figure 12) to aid in their identification, and we replicated the occurrence list (simulation events) to a dedicated tab to improve the visualization of the events (Figure 13).

3.4.3 *Development of the Gamified Version*

After completing the redesign phase, we developed the gamified version of the simulator using the Unity engine (version 2019.4.7f1). For the development, we started from version 0.9.18a of the simulator and used Git for version control. To ensure the persistence of student data and the functionality of elements like the ranking and history, we adopted Fire-

Table 4. Usability improvements (Part 1)

Previous version elements	**New Element**	**Justification for change**
The student's waiting screen displayed a progress bar with no information.	Text "Carregando" on the progress bar (Figure 14).	To indicate to the student that the simulation is loading.
The screen did not inform when the connection was lost.	Screen informs that the connection was lost and offers a "Reconectar" button (Figure 15).	To notify the student about the connection drop and allow them to reconnect to the simulator.
The text on the student login screen was "Entre suas informações".	Text corrected to "Entre com suas informações" (Figure 16).	Textual correction. To use the usual message seen in other systems.
On the student login screen, the button with the eye-icon (enter as spectator) was more prominent than the "ENTRAR" button and its function was not clear.	Visual standardization of the buttons and tooltip describing the action on the eye-icon button (Figure 16).	To guide the user to the main action ("ENTRAR") and clarify the function of the secondary action (spectator).
On the student login screen, the arrows to change the avatar image might not be intuitive.	Tooltips describing the action on the "Próximo" and "Anterior" arrow buttons (Figure 16).	To make the buttons' function clearer.
In the instructor environment, there were no tooltips on the simulation settings tab icons.	Tooltip on the settings tab icons .	To make the tab's content clear.
In the student environment, the background color of the command list and buttons was not standardized.	Standardization of the background color of the command list and buttons (Figure 14).	To maintain consistency and standardization.
In the student environment, it was possible to enter spectator mode without logging in.	The button is enabled only after filling in the login (Figure 16).	To prevent the student from accidentally entering without identifying themselves.
A simulation could be started with unfilled armored vehicles or with connected students not yet allocated.	The simulation start button is only enabled when at least one position in the armored vehicle is occupied, and until all students are allocated (Figure 17).	To prevent the simulation from starting until the instructor's allocation task is completed.
In the student environment, it was possible to try to connect to an ongoing simulation, even when it wasn't possible, leaving the student stuck on the "Aguardando início da sessão" screen.	The button to enter the simulation is disabled and a "Simulação em andamento" message is displayed (Figure 8).	To prevent the student from getting stuck in an infinite waiting state.
In the student environment, the waiting screen did not inform that the user was in spectator mode.	The waiting screen informs that the student is in spectator mode (Figure 18).	To improve context clarity for the spectator.
In the student environment, there was no information that the student was in spectator mode.	The screen displays "Espectador" and the eye icon (Figure 19).	To clearly communicate the spectator role.
In the instructor environment, the spectator was shown as "Função: Não atribuído".	Spectator shown as "Função: Espectador" (Figure 20).	To clearly communicate the spectator role.
The simulation could be started even if there were connected students without an assigned role.	Simulation prevented from starting with connected students without an assigned role (Figure 17).	To prevent the instructor from starting the simulation with connected students without an assigned role.
In the instructor environment, there was no feedback when the simulation settings were saved.	Feedback with a "Sucesso" message when saving the simulator settings.	To inform the result of the action.
In the instructor environment, there was no confirmation popup when saving or loading the simulation settings.	Confirmation popup when saving or loading the simulation settings.	To avoid accidentally saving or loading the simulation settings, losing the previous configuration.

Table 5. Usability improvements (Part 2)

Previous version elements	**New Element**	**Justification for change**
In the student and instructor environments, there was no confirmation popup to exit the simulation.	Confirmation popup to exit the simulation.	To prevent accidental exit.
In the instructor environment, it is not possible to end the simulation.	"ENCERRAR SIMULAÇÃO" button in the settings panel (Figure 12).	To improve the navigation flow.
In the instructor environment, the "Configurações" (three horizontal bars) and "HUD" (gear) icons were swapped regarding UI standards.	Icons adjusted (Figure 12).	To maintain consistency and standardization with design conventions (where a gear means settings).
In the instructor environment, the status of a disconnected student was not updated.	The disconnected student's status is updated to "Desconectado" (Figure 21).	To inform the real status of the students.
In the instructor environment, the message there are connected people without an assigned role was displayed even when all connected students had already been allocated.	Error corrected.	To update correctly.
In the student environment, the user could not identify when they reached the final destination.	At the end of the route, there is a signpost text ("Ponto B") (Figure 22).	To inform the end of the route.
The student's command keys "Q" and "E" (raise/lower) are not intuitive, and there is no button to exit the simulation.	The raise and lower commands are the up and down arrows, respectively. And there is a button to exit the simulation.	To make the controls easier to recognize (arrows = direction).
In the student's command list, there was no option to exit the simulation.	The command list has the option to exit the simulation (Figure 14).	To help with interaction with the simulator.
In the student environment, the command list was displayed in a non-standardized way.	Standardized command list (Figure 14).	To make it easier to recognize the commands on the screen.
The simulator did not generate a report of the simulation session.	The simulator generates the session report and lists it in the new tab (Figure 23).	To provide documentation to assist the instructor in the evaluation.
There was no way for the student to unlock the armored vehicle alone (Shortcut did not work).	Shortcut to unlock the armored vehicle (Spacebar) corrected.	To not cause confusion among students with a command that doesn't work.
The system does not record the student's cause of death.	Recording the student's cause of death in the report file.	The cause of death is important information for training.
The simulator did not use any symbol to inform that the student died.	On the instructor's screen, the student's icon turns red, indicating they died/disconnected, and light blue for other statuses (Figure 21).	To make it easier to recognize the students' statuses.
In the instructor environment, there was no shortcut to exit the simulation.	Shortcut to exit the simulation ("Alt" + "Q").	To help the instructor's interaction with the system during the simulation.
After the student's death, the final screen did not offer options to exit or return to the menu (it was necessary to close the Windows window).	"Sair da Simulação" button on the final screen after the student's death, in addition to the shortcut ("Alt" + "Q").	To provide options to exit the simulation.

Figure 11. Large font configuration (Gamified) (original in Portuguese). The English translation of the settings menu (left) is as follows: Screen Type: Windowed; Resolution: 1920x1080; Quality: Simple; Font Size: Large; Confirm; Cancel. The button on the bottom right translates to "Exit Simulation". For the English translation of the command list (right), refer to Figure 14.

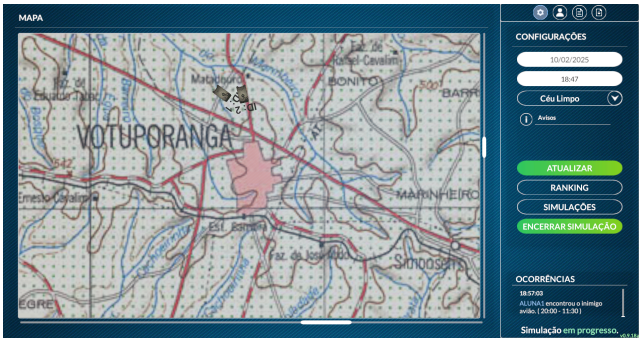

Figure 12. Instructor screen during simulation - settings (Gamified).

Figure 13. Instructor screen during simulation - occurrences (Gamified).

Figure 14. New loading screen (Gamified) (original in Portuguese). The English translation is as follows. Operator (M113 Control): W: Accelerate; S: Brake/reverse; A/D: Turn left/Turn right; Mouse (horizontal): Move camera direction; TAB: Open/close hatch; H: Turn headlights on/off. Commander (Rotate Platform): A/D: Rotate left/Rotate right; Left mouse button: Fire (continuous if pressed); TAB: Open/close hatch; L SHIFT (Hold): Enter aiming mode; Right mouse button (Hold, while in aiming mode): Move weapon direction. General: ESC: Settings menu; R SHIFT: Unlock/lock mouse; L CTRL: Open store; BACKSPACE: Unstuck; L ALT + Q: Exit simulation; Q/E: Move down/Move up. The interface also displays "Loading" progress bar at the bottom.

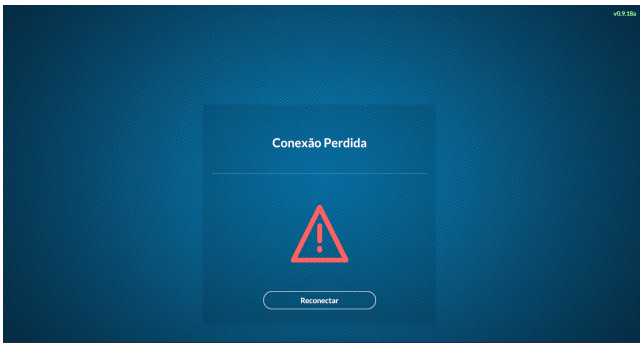

Figure 15. New connection drop screen (Gamified).

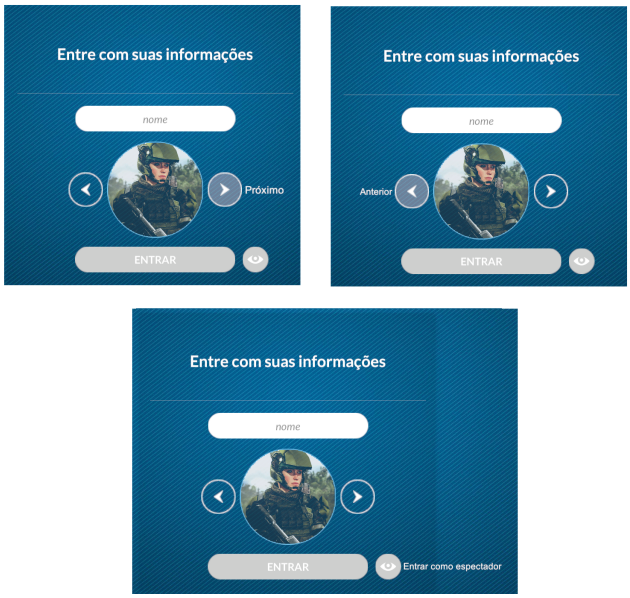

Figure 16. Captions on buttons (Gamified).

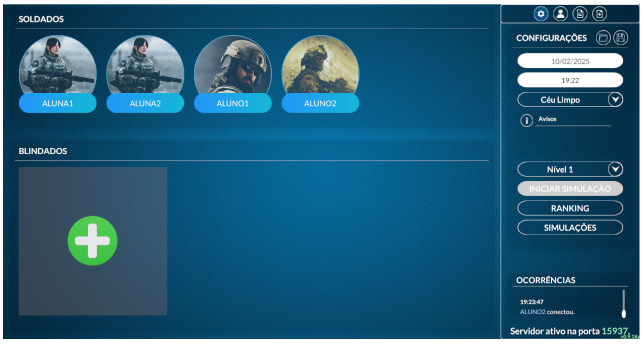

Figure 17. Instructor Home Screen (Gamified).

Figure 18. New simulation start waiting screen for spectator (Gamified).

Figure 19. New spectator simulator screen (Gamified).

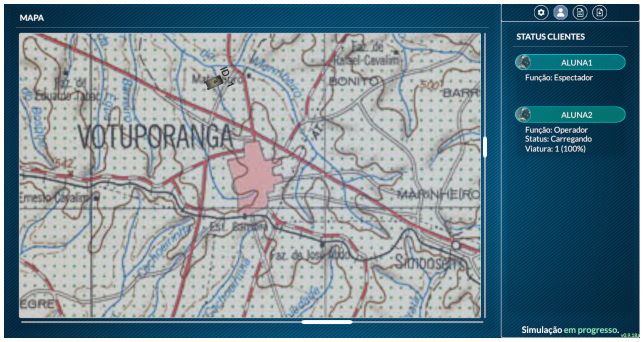

Figure 20. Instructor screen during simulation - status spectator (Gamified).

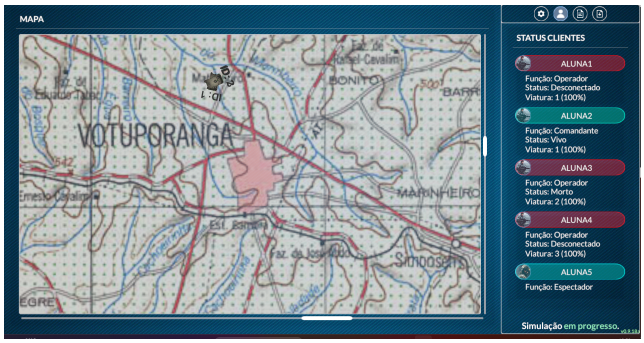

Figure 21. Instructor screen during simulation - client status (Gamified).

Figure 22. View of the military interface during the simulation and Visual *Feedback* (Gamified).

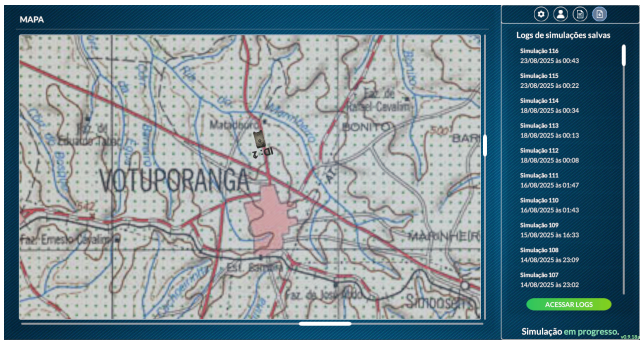

Figure 23. Instructor screen during simulation - saved simulation logs (Gamified).

store. As a NoSQL database, Firestore was used to enable the synchronization and querying of data required for the new gamification features.

3.5 User evaluation

Our objective with this evaluation was to collect the opinions of participants (students and instructors) on the use of each version of the simulator to understand their perceptions regarding the added gamified elements, investigating the challenges of their appropriation and which are suitable or not for the military context.

Participants. We recruited 16 male participants (14 students and 2 instructors), aged between 20 and 35 years, military personnel from the Simulation Laboratory of the Brazilian Marine Corps. All participants possess practical experience in real military training, having experienced analogous training situations in real life. This ensures they have the necessary competence to evaluate the simulation's fidelity and its alignment with real-world requirements. User participation was restricted to the time available and activities of the Institution. Before starting the study, each participant signed an Informed Consent Form, authorizing their participation in the study. Students are identified in the study as A1, A2...A14, and instructors as I1 and I2.

Procedure. We conducted the tests in a hybrid format, with participants being at the Brazilian Marine Corps Technological Center, one of the Brazilian Marine Corps science and technology institutions, along with one of the researchers who organized and led the session, while another researcher followed remotely, giving instructions and conducting interviews in the second stage.

The testing session lasted for 7 hours and was divided into two stages, each dedicated to evaluating one of the simulator versions. The order of the versions was counterbalanced across participants to control for order effects. Each stage consisted of using one simulator version and participating in a semi-structured interview to gather participants' opinions/perceptions of that version.

Initially, we explained the work and the two stages of the session. After obtaining consent, we gave the participants a map of the route and command instructions, and provided them with five minutes for familiarization with the simulator and to clarify any doubts. Next, we divided them into two groups: Group 1 (8 participants) and Group 2 (6 participants). In the first stage, Group 1 used the non-gamified version and Group 2 the gamified version; both had 30 minutes for exploration and training, with the gamified version phase

limited to 20 minutes, as it is necessary to establish a time limit to complete the mission in it. In the second stage, the groups switched simulator versions, repeating the procedure and usage time.

Data collection. We collected the data through conversations from semi-structured interviews applied to participants via recorded telephone calls. We elaborated different scripts for each evaluation stage and for each simulator version. The interviews applied after using the non-gamified version contained questions related to the experience and opinions about the version used. In contrast, those applied after using the gamified version, in addition to the questions contained for the non-gamified version, included others regarding each applied game element.

Another difference is that for the interviews after the second use, there were comparison questions with the first version used. Finally, we also differentiated the interview script according to the role played. The questions for the students focused on their own usage experience and interaction with the game elements, while the instructor's focused on the perspective of training evaluation, the utility of support tools (such as logs), and the influence of game elements on the students' training.

The semi-structured interview scripts can be accessed in the supplementary material. Some questions were adapted or omitted based on the participants' answers during the interview.

Data Analysis. We analyzed the interview data using the qualitative method of Thematic Analysis [Braun and Clarke, 2006]. This method allowed us to identify, organize, and find patterns (themes) in the data. We followed the six methodological phases as detailed by Souza [2019].

In Phase 1, we transcribed the interview audio with the help of the AI *Gemini* (with our review and correction). Shortly after, we organized the data into spreadsheets with questions and answers, and read them repeatedly to identify patterns and categorize initial code candidates (small excerpts that summarized interviewees' speeches/opinions) based on gamification elements, fidelity to the training, and other categories that emerged and proved to be important. In Phase 2, starting from the set of previously generated code candidates, we systematically coded the data. To do this, we reviewed our spreadsheets and created a table with the identified initial codes, and for each of them, we associated exemplary extracts.

In Phase 3, we grouped the codes into themes, resulting in an initial thematic map. In Phase 4, we reviewed and refined the themes, evaluating their internal coherence (in relation to the extracts) and their overall validity (in relation to the dataset). This led us to alter the themes and consequently the thematic map. As a result, we identified six themes: the theme "The Value of the Simulator as a Training Tool" which addresses general perceptions regarding the tool's utility; "Evaluating Simulator Functionalities (Gamified or Not) Against Military Reality" focusing on the simulator's fidelity and relevance compared to real-world military scenarios, serving as a qualitative validation of the simulation's fidelity, as participants used their domain expertise to assess the coherence of the information presented against real-world; "Impact and Perception of Gamification Elements in Experience and Training" investigating the influence of game elements on the training process and the overall simulator experience; "Visibility and Functionality Appropriation Challenges" dealing with features left unused due to lack of time or visibility; "Simulator Appropriation and Usability Challenges (Gamified or Not)" encompassing technical and operational obstacles that hindered interaction; and, finally, "Suggestions for Optimizing Simulation and Training" which gathers user recommendations to improve the simulator.

Moving on to Phase 5, "Defining and naming the themes", we developed the initial narratives and renamed some themes to better reflect their content, and adjusted the thematic map again, resulting in the final version illustrated in Figure 24. For each theme, we reviewed the associated codes and extracts to develop a definition of its central idea. To create the narrative for each theme, we organized the codes and wrote them in a way that connected the interviewees' perceptions, using their extracts to support the information presented. Finally, in Phase 6, "Producing the report", we used the themes and their narratives to write the analysis available in sections 4 and 5.

4 Results

Thematic Analysis identified six themes on participants' perceptions and experiences with the simulator, focusing on gamification and its suitability. We present and discuss each theme, with excerpts from participants' statements.

Theme 1. The Value of the Simulator as a Training Tool. We found that the simulator is valued for military training because it saves resources. According to A10, the simulator allows training *"without all that hassle of [...] spending on fuel, on [...] real ammunition"*, an idea reinforced by A11, who stated that its use *"reduces costs, you know, for the Navy, [...] you won't spend fuel, you won't spend ammunition"*. This makes the practice more frequent and accessible.

The simulator offers a safe environment for training, as it allows *"putting into practice what we need to perform, such as communication, such as what attitude to take in front of an enemy..."* (A9). The motivation to use it seems to stem from interactivity and its role in skill development, not necessarily from gamification, with I1 reporting that *"Everyone who [...] went through it liked the experience"* and that *"if there are more [...] opportunities, everyone will want to participate"* (reported in both versions), with the gamified version being *"quite interesting [...] as a training method"* (A11) and the non-gamified one being of *"great value [...] for us to be training our tactics"* (A8).

Adaptation to the second use is also evident, even altering the order of application of the versions, with I1 observing that the second use *"was much better [...] They were already a little more accustomed [...] with the control [...] of the simulator"* (report after the second use of the gamified version) and I2 affirming that *"...the personnel were already more familiar, [...] it was more dynamic"* (report after the second use of the non-gamified version).

Theme 2. Evaluating Simulator Functionalities (Gamified or Not) Against Military Reality. We found that military reality is the fundamental criterion in evaluating any functionality, gamified or not, with its acceptance depending on the ability to reflect or prepare for real scenarios. Elements

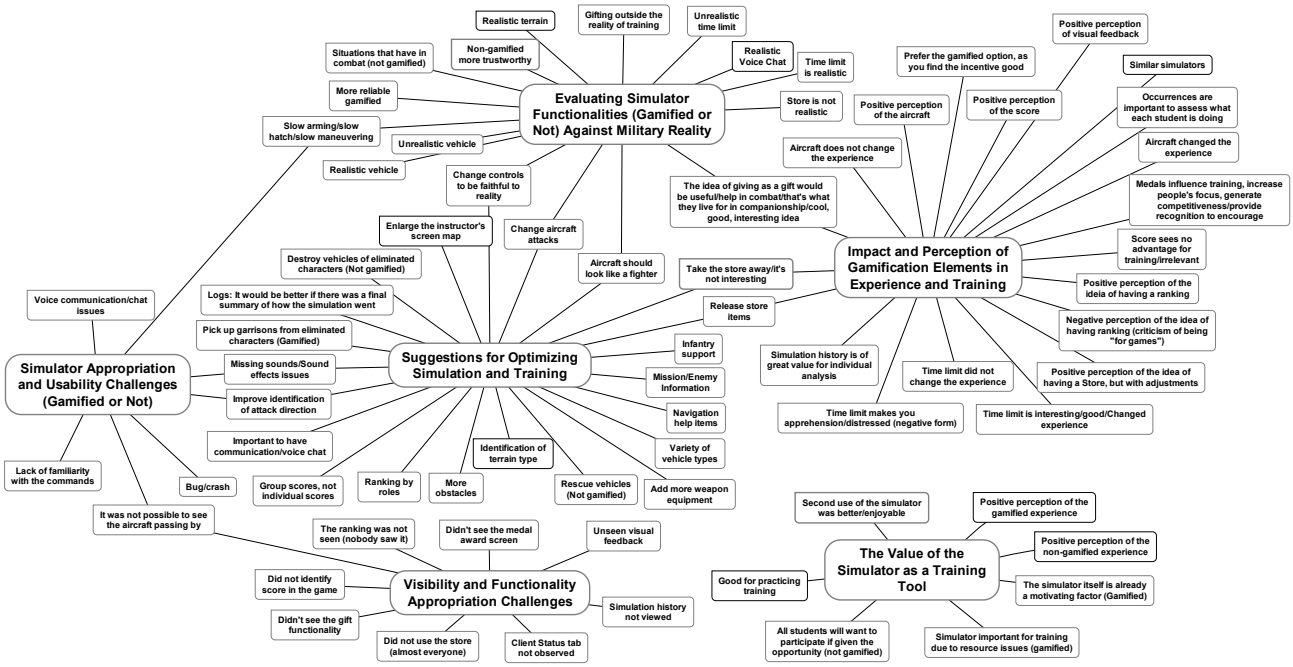

Figure 24. Thematic map showing the relationship between codes and the resulting themes.

that are purely playful or contradictory to military practice tend to be rejected or seen as inappropriate.

The shop, for instance, was criticized for deviating from realism. According to A9, *"if the game's intention is to truly simulate reality, I don't think that idea is very plausible, because if it were in reality, [...] everyone would start with the same equipment, you know?"*. Perceptions of fidelity vary among participants, such as the idea of gifting, which was received by A8 as something that makes the simulation *"more of a game than a simulator [...] more for fun"*, but which for others is interesting because it simulates (*"...what they experience through camaraderie..."*, A14). Similarly, the time limit functionality, which for A10 is unrealistic due to the dynamic and unpredictable nature of real operations (*"...in a real operation, that's also very relative..."*), is for others a limitation present in the reality of missions (*"...the mission, it has a time, right? It doesn't have unlimited time..."*, A14), suggesting that a gamification element can be perceived as realistic if it finds a relationship in military values or practices.

The aircraft, on the other hand, received criticism, such as from A11 regarding its disproportionate size and speed (*"...the aircraft's size became a bit disproportionate..."*), demonstrating the importance of visual and behavioral fidelity. Furthermore, criticisms focused on "Unrealistic vehicle" and "Slow weaponry/slow hatch/slow maneuvers", as well as suggestions to "Change controls to be faithful to reality", show that fidelity is also linked to its practical execution in the simulator: if the handling of weapons, for example, is not satisfactory, even if it exists to simulate a real action, the perception of unrealism can arise because the simulated experience does not achieve the expected operational capacity.

For some, like A9, the absence of elements like rankings and scores in the non-gamified version makes the simulation *"more realistic because it didn't have this issue of rankings, scores..."*, indicating that, for these students, gamification can diminish the feeling of being in real training.

Theme 3. Impact and Perception of Gamification Elements in Experience and Training. We found that elements such as medals (*"it makes it a bit more competitive [...] it increases the focus of the group."*, I2) and ranking can increase motivation, but risk diverting focus from the main training objective if not carefully integrated and justified. According to A12, ranking can *"encourage [...] people to improve when using the simulator"*, but A11 expressed concern that it could encourage individualistic behaviors and distract from the main mission: *"on the level of a military exercise, uh, for me it's irrelevant [...] you're going to want to kill the enemy, you're going to want to be the first place. [...], sometimes you don't necessarily have to engage [...], but then you'll have that mentality of scoring, you understand? And the point is to complete the mission"*.

Other elements divided opinions: For A4, the time limit was interesting for simulating pressure (*"I liked it. I found it interesting because you are more under pressure, right? You try to think faster, act faster"*), but for A8, it generated apprehension (*"Yes, it causes anxiety because you want to complete the mission and time is running out"*); for A12, scoring is *"Well, it's a way to encourage, right? An incentive during the simulation"*, but for A2, it is irrelevant for training: *"I don't think it's very relevant, from my point of view, the scoring"*. Elements that present realistic tactical challenges, such as the aircraft, which was seen by A1 as an *"effective"* and *"interesting"* element that adds a *"surprise effect"* (*"It's very, also effective, uh, right? Causing the surprise effect on our TAI, right? Our immediate action technique. Very interesting"*, A1), or that improve situational clarity, such as visual feedback (*"I thought it was good, important. So that we become aware of the game's situation and I thought it was necessary"*, A9)), tend to be well-received.

The idea of elements like simulation history was per-

ceived by instructors as an evaluation tool (*"it's important for us to evaluate what each person is doing there in... in the given situation"*, I2). On the other hand, although the idea of the shop generated an initial "positive perception" due to the possibility of *"equipping oneself further"* (*"It's interesting [...] because you can equip yourself more, right? Be better prepared"*, A4), this perception was accompanied by the caveat that adjustments would be necessary, such as releasing basic items (*"Yes, I think a compass should already be valid from the beginning. [...] Uh, now accessories, like, like ammunition, like weaponry, I think it's valid... To exchange points [...] for weaponry"*, A8).

The perception that the gamified and non-gamified versions are similar by some participants (*"I thought it was all the same, right? The difference is that there was more [...] there was a shop, right?"*, A13) suggests that the addition of gamification elements may not have been impactful enough to transform the core simulation experience for everyone.

Theme 4. Visibility and Functionality Appropriation Challenges. We identified that the existence of a feature in the simulator does not guarantee its use. The presentation of these features on the interface, both the gamified and the basic ones, limited interaction, as some participants failed to notice them. For example, some students "Did not identify in-game scoring" (*"...I didn't even identify these scores during the game"*, A9). Similarly, both instructors reported that they "Did not see the medal awarding screen" (*"No, I didn't interact with it. I didn't interact with that screen"*, I2).

This lack of perception extended to other elements; some students reported that "Visual feedback was not seen" (*"So, I also couldn't see this feedback"*, A8), and the "Simulation history was not seen" by any of the participants (*"No, I didn't get to open that history"*, A12). Likewise, "The ranking was not seen" by any participant (*"Actually, I didn't get to see this ranking system"*, A14). The gifting functionality (*"I didn't use this, this system"*, A1) is another example of non-perception. All participants reported that they "Did not use the shop", often justifying it with a lack of time (*"There wasn't even enough time"*, A5). This suggests that the integration of elements into the main simulation flow and their perceived relevance need to be carefully considered in the design. Furthermore, the compass was available in the non-gamified version (allowing the instructor to add it to the students' screens), but "nobody saw or used it", even though they reported experiencing difficulty due to its absence (*"we still felt the difficulty, uh, due to the absence of the compass there"*, A10) and that the simulations should have started with it (*"...the compass, right? A map, it could have started already and not be in the shop"*, A12), indicating that appropriation challenges may be related to interface clarity, not just acquisition mechanics.

Thus, before evaluating the impact or suitability of a functionality, gamified or not, it is crucial to ensure that users are aware of its existence and know how to access and utilize it.

Theme 5. Simulator Appropriation and Usability Challenges (Gamified or Not). We identified that usability and appropriation challenges, such as familiarization with commands (*"...Then I had difficulty with the commands, right? [...] Looking for the command on the computer"*, A11), technical issues (*"...we couldn't hear the enemy shots..."*, A2), and communication limitations ("*...the headphone feedback isn't responding properly either. Not being able to hear or speak"*, A7), negatively impacted participants' experience with the simulator. This can break immersion and compromise confidence in the tool as a serious and reliable training environment.

The failure of the voice chat in the gamified version may have prevented a complete evaluation of the element itself. Additionally, system stability (*"...it flipped over, it started somersaulting in the air"*, A13) and control responsiveness (such as slow weapon handling (*"I just found it a bit, a bit slow there..."*, A12)) are also important for maintaining immersion and allowing for skill application.

Overcoming these challenges is a prerequisite for both the simulator's basic functionalities and the additional gamification elements to be utilized, perceived, and evaluated.

Theme 6. Suggestions for Optimizing Simulation and Training. We identified that participants demonstrated a desire for a simulator that serves as a realistic and effective training tool, with suggestions focusing on increasing the fidelity of controls (*"...the control would have to be more faithful to our reality..."*, A2), scenarios (*"...put in more obstacles [...] like the aircraft, put more people shooting."*, A13), and operational dynamics (*"Uh, when a vehicle gets stuck in the terrain, uh, we have the capacity to use another to retrieve it..."*, I2).

The suggestions for gamification elements (ranking, scoring, shop) indicate an openness to their inclusion, provided they are adapted to reflect the reality of the military context, such as teamwork, with the suggestion for "Group scores and not individual" (*"...it could be an incentive for a particular group"*, A12) and "Ranking by roles" (*"...Maybe it can be done within the same role. [...] Now, across different roles, I don't know if it would be so [...] realistic there"*, I1), making the competition fairer and more relevant to them. For the shop, the suggestion is that it should only be for resupplying material (*"The ideal is if we could, uh, insert them, at least in one or more vehicles from the beginning. And that others could even be acquired during the time, but the ideal is that from the beginning we have the resources"*, I2).

Students repeatedly reported the lack of "Navigation aid items", such as compasses (*"One thing that we felt, that we felt was missing, was precisely having some orientation..."*, I2). Some suggestions highlighted the need for greater clarity in the presentation of information and resources (*"...regarding the enemy's situation, knowing what type of weaponry the enemy has..."*, A9). Another point is the voice chat functionality, which is considered important for training (*"...if there was the possibility, uh, of having communication [...] between the vehicle's occupants and externally between the vehicles[...]it would certainly be a very big gain"*, I1).

The suggestions to enrich the simulated environment and analysis tools, such as detailed logs (*"...A final evaluation of everything there, for us to understand how this whole dynamic went..."*, I2), reflect a desire to increase the simulator's value for training.

5 Discussion

Based on these results, this section discusses the findings by answering the proposed research questions (RQs):

RQ1: Which gamification elements are perceived as suitable in a military training simulator?

We present below the elements with the reservations and adaptations necessary to integrate them into the military context.

- **Visual Feedback:** Generally well-received for providing situational clarity, which can contribute to training and the fidelity of the experience by making the consequences of actions more apparent. As A9 comments *"I thought it was good, important. For us to be aware of the game's situation and I found it necessary"*.
- **Aircraft (as a challenging game element):** The introduction of another tactical challenge, such as aircraft, was perceived as a valuable additive that can increase the realism and complexity of training, provided that its representation and behavior are faithful. As A1 comments *"...it changes the tactical aspect of training, forcing the search for shelter"*.
- **Gifts (when linked to camaraderie):** The mechanic of gifting items found positive reception when interpreted as a reflection of military camaraderie. This suggests that collaborative elements of gamification may be suitable if aligned with the values of military culture. As A9 comments *"...if any, some soldier loses some equipment and you have it and you don't [...] I think the idea of passing it to another one is cool"*.
- **Scoring and Ranking (with significant adaptations):** While individual scoring and ranking have been criticized by some as *"gets more [...] games"* (A9) and potentially detrimental to mission focus and teamwork (A11), suggestions for "group scoring" and "ranking by roles" indicate an openness to these elements if they are adapted to reflect the collective nature of military operations. Incentive and competitiveness can be beneficial if channeled correctly. As A12 comments *"Eh [...] even regarding the issue of [...] I think the incentive, I think it's good. And it could be, like, eh, instead of being an individual incentive, it could be an incentive for a certain group. Like, the group fulfilled [...] the [...] the objectives, ah, performed the maneuvers and everything. Then it could be a score for [...] for the group, and not individualized, you know?"*.
- **Medals (as recognition):** They can be suitable if used to acknowledge student performance, but their implementation was not perceived by instructors in the study. As I2 comments *"it makes it a little more competitive, right? There, it makes... increases the focus of the group"*.
- **Time Limit (with ambiguous perception):** While some believe it generates apprehension (which appears to be a negative aspect), for many others it is seen as realistic. Its suitability heavily depends on how it is implemented and justified within the context of the scenario. As students A4 and A8 comment respectively *"I liked it. I even found it interesting, because you are more under pressure, right? You try to think faster, act faster"* and *"Yeah, you get a bit apprehensive there, because you want to complete the mission and time is running out"*.
- **Voice Chat:** A functional voice chat is perceived as essential for training. Its successful implementation contributes positively. As I1 comments *"...if there were the possibility, uh, of having communication [...] among the vehicle's members and externally among the vehicles [...] it would certainly be a very big gain"*.
- **Simulation History (as training progress):** Although it was only visualized by the instructors, it proved to be useful for them, as it allowed them to track development in training. As I2 comments *"Yes, it would be [...] uh [...] of great value to have [...] to have this [...] this document there to see how each person proceeded in [...] in the given situation"*.

RQ2: Which gamification elements are perceived as less suitable or reduce simulation fidelity in a military training simulator?

- **Item Shop (for basic equipment):** The mechanic of "buying" essential operational items was heavily criticized as unrealistic and a departure from military practice. The recurring suggestion was to release these items from the outset. As A9 comments, *"Ah, I think that, if the game's intention is really to simulate reality, I don't think this idea is very plausible, because if it were in reality, [...] everyone would start with the same equipment, you understand?"*
- **Gifting (if seen as purely playful):** If the gifting mechanic is unjustified or feels artificial, it can be perceived as detracting from the seriousness of the training. As A8 comments, *"more of a game than a simulator [...] more like that for fun"*.
- **Individualized Ranking:** May encourage behaviors misaligned with teamwork and mission accomplishment. As A11 comments *"Yeah. Look, on a military exercise level, uh, for me it's irrelevant [...] you'll want to kill the enemy, you'll want to be the first one. [...], sometimes you don't necessarily have to engage [...], but then you'll have that mentality of scoring, you understand? And the thing is you have to complete the mission"*.

RQ3: In what way do gamification elements contribute to the military training process?

- Elements that increase tactical challenge (aircraft), provide clarity (Visual feedback), encourage collaboration (well-contextualized gifts, group scoring), foster motivation (ranking, if by roles), or provide recognition (medals) have a greater potential to contribute positively to training. As A1 and A9 comment respectively, *"...adds a surprise effect"* (Aircraft) and *"...provide clarity on simulation events..."* (Visual Feedback).
- Distracting elements or those perceived as unrealistic (e.g., a shop for basic items and ranking when done individually) can harm the focus on training military procedures. As A9 comments *"Ah, I think that, if the game's intention is really to simulate reality, I don't think this idea is very plausible, because if it were in reality, [...] everyone would start with the same equipment, you understand?"* (Shop).

RQ4: What are the perception and appropriation challenges associated with gamification elements in a military training simulator?

Regarding the perception challenges, we identified the following:

- One of the challenges is that some gamification elements, such as ranking, are perceived by participants as typical of games and may not fit the seriousness and objectives of military training. As A6 comments, *"Ah, I don't think it adds much to the training itself, it's more in the gaming part"* (Ranking).
- The perception of the relevance of a gamification element is linked to its perceived fidelity to military reality. Elements that break this fidelity are perceived as inadequate by participants. As A4 comments, *"I also found it interesting because it seems more like reality, right? Because in the vehicle in real life it's like this"* (Chat).
- The concern that individual rankings might harm team spirit is a significant perception challenge. As A11 comments *"Yeah. Look, on a military exercise level, uh, for me it's irrelevant [...] you'll want to kill the enemy, you'll want to be the first one. [...], sometimes you don't necessarily have to engage [...], but then you'll have that mentality of scoring, you understand? And the thing is you have to complete the mission"* (Ranking).

Concerning the appropriation challenges (affecting both gamification and core functionality) of gamification elements in a military training simulator, the results indicate the following:

- **Visibility and Discovery:** Many gamification elements (shop, badges, ranking, gifts, simulation history) and basic functionalities (compass in the non-gamified version, command to get unstuck) were not seen. This hinders their appropriation. As A9 commented *"...I didn't even identify these scores during the game"* (Score).
- **Lack of Time and Prioritization:** The dynamics of the experiment simulation, with limited time for exploring the simulator and the core tasks, may have led participants to not explore functionalities perceived as secondary, including many of the gamification elements. As A12 comments *"No, there wasn't time to get to, there wasn't time to buy anything in the store, no"* (Store).
- **Familiarization with commands:** Initial difficulty with the simulator's general commands may have camouflaged attention to gamification elements or more specific functionalities. If basic interaction is a challenge, the appropriation of additional elements becomes even more difficult. As A6 comments *"...Then I had difficulty with the commands, right? [...] Searching for the command on the computer"*.
- **Technical Issues:** Failures such as the voice chat in the gamified version prevented the appropriation of the element. As A7 comments *"...the headphone feedback isn't working either, it's not responding properly. I can't hear or speak"* (Voice chat).
- **Lack of Clear Instruction:** The lack of knowledge about functionalities such as unsticking indicates that the introduction and familiarization process with the tool needs to be more effective to ensure the appropriation of resources. As I2 comments *"Uh, when a vehicle gets stuck on the ground, uh, we have the ability to use another one to retrieve it..."* (Unsticking).

6 Conclusion

The analysis of participants' perceptions of the SiBART simulator, covering its gamified and non-gamified versions, showed the perception of the **tool's value (Theme 1)** and the search for **operational fidelity (Theme 2)**. These two pillars serve as the foundation for the acceptance of **gamification elements (Theme 3)**. Although the simulator is recognized as a valuable resource, mainly for resource optimization and its ability to promote training, the performance and acceptance of the addition of gamification elements are influenced by its capacity to reflect military reality and by overcoming **challenges in the visibility of functionalities (Theme 4)** and **general appropriation challenges (Theme 5)**.

Participants continuously use military reality as a criterion. Gamification elements that align with military values, such as camaraderie (when gifting), or that introduce relevant tactical challenges (aircraft), tend to be well received. However, mechanics that contradict military reality (such as a store for basic operational items or rankings that encourage focus on the individual rather than team collaboration) cast doubt on their relevance in the simulator.

Furthermore, the existence of functionalities, whether basic or gamified, does not guarantee their utilization. The way the elements were displayed on the interface limited interaction, as some participants failed to notice the presence of these resources. This demonstrates that, before assessing the suitability of a gamification element, a study must be conducted on how it should be displayed on the interface to ensure appropriate integration with the simulated environment, thus making it noticeable by users. Technical challenges, such as bugs, also hindered the experience.

The numerous **optimization suggestions (Theme 6)** offered by participants may indicate a desire for a tool that is effective. The proposals aim to increase the realism of scenarios and controls, improve usability, enrich tactical options, and adapt gamification elements to serve the purposes of military training, such as group scoring and the provision of essential resources without the need for purchase.

Finally, it is important to note that some gamification elements included, although perceived as interesting or relevant to the military in the initial evaluation, did not receive a good reception after being implemented in the simulator. This highlights that the inclusion of such elements in this type of simulator requires more in-depth studies and different evaluations to meet expectations.

In conclusion, the successful integration of gamification into the SiBART military simulator depends on a design that prioritizes fidelity, aligns game elements with military values and practices, and ensures all functionalities are visible. Overcoming appropriation challenges, through improved interface design and effective onboarding processes, is important for both the simulator itself and the gamification elements to reach their full potential as training tools.

6.1 Limitations

It's important to acknowledge some limitations of this study. First, the military personnel had a relatively short time to use the different versions of the simulator before the interviews. This may have restricted their full familiarization with all the features and, consequently, influenced some of their perceptions. Additionally, the number of students who participated in the experiment was a limited sample. There were only 16 participating students due to restrictions on available personnel to conduct the experiment. Although this was enough for us to identify important perceptions, a larger group could provide a more consistent basis for generalizations.

Another time-related limitation was the short period of simulator use, restricted to just one day, which was the day of the experiment, due to the participants' limited schedules.

The gamified version of the simulator included usability improvements [Zilberberg, 2019], this may have influenced users' perceptions of the gamification elements.

Finally, we identified a technical problem with the headsets during the simulations, as noted during the interviews. The voice chat feature, one of the implemented gamification elements, did not operate as expected, and this failure was only noticed after the simulation sessions were completed. This limited the communication experience and the participants' perception of this feature. It is also important to note that our study only measures the users' perception and acceptance of the gamification elements and not their performance on the simulator. The evaluation of student performance is not measured by the simulator, only by instructors who evaluate the simulation, therefore, at this time, it was not possible to perform this step.

6.2 Future Work

We can suggest several avenues for future work, such as conducting studies on how gamification elements should be displayed on the interface to ensure appropriate integration with the simulated environment, thus making them noticeable by users. We also encourage studies focused on the personalization of these gamification elements in the simulator to better meet the needs of each user. Also, conducting new evaluation cycles with the simulators, allowing participants to use them for extended periods. This would enable greater adaptation to the functionalities of both the gamified and non-gamified versions. Future studies could also involve larger groups of participants, aiming to increase the representativeness of the results. It would also be important to implement the identified findings and suggestions for improvement in a new iteration of the simulator SiBART. After these implementations, a new comparative evaluation could be conducted.

Declarations

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Authors' Contributions

TB, GS, and AR collaborated on the conceptualization of the study. The methodology was developed by TB and GS, and the investigation phase was conducted jointly by TB, RS, and GS. RS and AR provided the necessary resources. TB was primarily responsible for the software development, data curation, formal analysis, visualization, and writing of the original draft of the manuscript. The overall supervision of the work was carried out by GS and AR. GS also contributed to the review and editing of the text. . All authors have read and approved the final version of the manuscript.

Competing interests

The authors declare that they have no competing financial or non-financial interests that could have influenced the work reported in this article.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to the sensitive nature of the research involving a military institution and to protect the privacy of the participants. Only the interview and questionnaire formats used in this study are available at https://doi.org/10.5281/zenodo.17693710, Create on 24 November 2025.

Further relevant information

The authors declare that the Gemini Artificial Intelligence (AI) tool was used to assist in transcribing the interviews, with all transcriptions subsequently reviewed and corrected by the researchers to ensure accuracy.

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