

# A Structured Approach for Designing Effective Serious Games for Learning: Analyzing Requirements to Derive Key Components

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**Abstract:** Recently, serious games have attracted significant interest as learning tools in various educational and training fields. They have emerged as powerful resources for improving learning outcomes. In this research, we explore the potential of virtual experiences and game-based applications beyond the entertainment industry and examine their multifaceted impact on education. We identify and conceptualize the functional requirements and aspects involved in developing and enhancing serious games for learning. These requirements form the basis for constructing concrete components that are reusable and applicable across different domains and learning topics. They can facilitate the design process, give the development team access to high-quality and up-to-date components, and support collaboration among multidisciplinary teams. Additionally, they help reduce the complexity and effort associated with serious game design. These components are categorized into three groups to form a conceptual framework: serious game structural components, behavioural dynamics components, and user experience enhancement components. To demonstrate the applicability of the proposed approach, we applied it to develop a serious game as a web application and to redesign an existing serious game. The results indicate that our framework provides clearer guidance for integrating gaming and educational aspects, allowing for more detailed composition of game components and alignment with learning objectives. It offers graphical and textual representations of serious games, simplifying comparisons of different games and offering insights into game challenges and player engagement. Furthermore, it can be a valuable tool in providing a quick, practical reference for the development team. It helps the development team better understand the complexity of serious game design, find new ideas on how to improve games, and create high-quality, effective games.

**Keywords:** Serious games, Functional requirements, Game components, Game development

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## 1. Introduction

Serious games are interactive applications that merge educational content with engaging gameplay by embedding learning objectives within a fun, motivating environment. This approach encourages players to keep playing—and consequently, keep learning and achieve better learning outcomes (Silva, 2020). Due to this characteristic, serious games play an essential role in education and have become an impactful teaching resource. They are an effective tool for engaging today's generation of learners, who are deeply familiar with technology. By leveraging modern technologies, serious games offer immersive, multi-sensory learning environments that intellectually challenge students while maintaining their interest (De Gloria et al., 2012).

Designing serious games that effectively align with specific learning objectives is challenging. It requires substantial effort to integrate pedagogical content into gameplay. The development process typically includes game design, software development, and the integration of pedagogical elements. Therefore, it involves close cooperation among multidisciplinary teams to ensure that the games are both educationally effective and engaging while meeting the students' needs. This complexity often leads to difficulties, as multidisciplinary teams may use different vocabulary and have different perspectives on the game, which can cause misunderstandings and hinder effective communication. Sparse research has been conducted to address this problem. However, existing work is often more theoretical and does not clearly distinguish the entertainment aspects from the educational content, which makes communication among the development team still difficult. In this paper, we argue for a cooperative environment that enables the development team to understand each other and communicate using a common language.

This research aims to improve the development of serious games while reducing associated costs and effort. We define the functional requirements of the design process and propose a structured framework to guide serious game development. This framework facilitates multidisciplinary team collaboration, identifies reusable components, and streamlines development steps to enable the creation of compelling learning experiences.

Our approach offers a roadmap for conceptualizing the design, development, and functioning of serious games, providing a high-level view of the key elements involved. It is valuable for educators, developers, and researchers seeking to enhance game-based learning methodologies. It encompasses high-level concepts for representing games and pedagogical aspects to help the development team build high-quality, up-to-date components.

Even though there are many existing design frameworks and approaches that offer valuable ways of designing, developing, and analysing serious games (e.g., Arnab et al., 2015; De Freitas & Jarvis, 2006). Each tends to focus

on different aspects of game design and on documenting the design process at a high level. These works have helped clarify the opportunities and limitations of serious games and explain why this type of game can be a promising tool for learning. However, they do not fully explain how the concrete components of a serious game should be structured and implemented to simultaneously achieve high levels of learning effectiveness and entertainment value. Our approach provides additional criteria and a practical basis for designing high-quality games, particularly within interdisciplinary development teams. It aims to fill the gap between the theoretical understanding of what makes an effective game and the practical steps required to achieve this in detail. Therefore, it offers a more holistic approach to game design and enables the development team to better address motivational and affective aspects of gameplay, which have been underrepresented in prior taxonomies.

This paper is organized as follows: Section 2 describes our literature review concerning the derivation process of serious games requirements. Section 3 presents our framework components. In section 4, we demonstrate its applicability by modelling serious games. Finally, conclusions are given in section 5.

## **2. Deriving Functional Requirements across Serious Games**

In this section, we analyse the domain of serious games by conducting an in-depth literature review. This investigation aims to provide a foundation for identifying functional requirements across different genres and topics of serious games. The goal is to highlight elements with high reusability potential for cross-domain applications and learning contexts, and to derive modular components based on these requirements. A crucial first step in identifying these requirements is to decompose the domain into its functional areas, subsystems, and desired goals. This helps determine relevant elements and high-level business use cases, which can then be selected as potential candidates for software modules or functionalities. This approach is commonly adopted among several methodologies for system development (Jaakkola & Thalheim, 2011). The requirements are identified based on: their potential for reusability across various serious games and learning contexts, particularly within the same game genre, and their relevance to enhancing the educational effectiveness of serious games.

According to their domains, these requirements are clustered into seven categories: pedagogy/learning, rules, interaction and communication, assessment, goals, adaptation, and representation, as shown in Table 1.

The identified requirements represent key functionalities that can be incorporated into serious game design as reusable components. Among them, assessment and adaptation are critical elements in educational research and are essential for creating effective learning environments. These factors are considered core functional requirements in the serious games conceptual framework, as they are applicable across different genres and domains and can be abstracted as external modules. In many cases, the functionalities are broad enough to allow for the potential integration of solutions from non-gaming contexts. Their integration significantly enhances game effectiveness and supports educational objectives and engagement. The following sections present key findings and evidence for each category, offering insights into the essential requirements for refining serious games design.

### **2.1 Pedagogy/Learning**

This category describes the essential educational concepts of serious games, such as identifying educational methods, enabling practice and repetition, defining learning objectives, and supporting knowledge transfer. These elements are general enough to be considered as functional requirements.

*Identifying the educational approach:* A serious game based on pedagogical aspects should integrate multiple learning processes—social (situational), task-centered (associative), and constructivist (cognitive)—leading to the first requirement:

FR1: A serious game must offer object-focused interaction mechanisms, have task-centered goals, and also give the possibility to learn/play in social groups.

*Training and repetition:* essential for reinforcing skills and achieving learning outcomes, it leads to the second requirement.

FR2: A serious game should provide the ability to present learning objectives through repetitive tasks.

*Learning Objectives:* In serious games, learning objectives depend heavily on the game's context, especially regarding learning actions. Games must clearly present problems and learning content by integrating different

mechanisms such as objects, NPCs, or gameplay elements to directly communicate objectives. This leads to the third functional requirement:

FR3: To introduce the learning objectives, a serious game must provide interaction mechanisms.

*The transfer of knowledge and skills*, both within the game and between the game and real-world contexts, according to that, we formulate this requirement.

FR4: A serious game should be designed in a way that supports the progressive introduction of new skills during play.

Finally, the success of serious games depends heavily on correctly identifying educational approaches appropriate to the specific domain and target audience, ensuring that the game’s design effectively supports the intended learning processes.

**Table 1: Effective factors for serious games**

Category	Factor	Description
1. Pedagogy /Learning	Identifying the Educational Approach (Kazimoglu et al., 2010; Yusoff et al., 2010; Zaibon& Shiratuddin, 2010; De Freitas& Jarvis, 2006).	Identifying information about how to facilitate the learning process and introduce easy-to-perceive content.
	Training and Repetition (Kazimoglu et al., 2010; Yusoff et al., 2010; Zaibon& Shiratuddin, 2010; De Freitas& Jarvis, 2006).	Providing the ability to frequently and effectively practice learning content.
	Learning Objective (Carvalho et al., 2015; Prensky, 2001; Yessad et al., 2010)	Describing the desired learning outcome that the players should have acquired at the end of a game or a learning level: skills and attitudes.
	Transfer of knowledge and skills (Yusoff et al., 2010; Zaibon& Shiratuddin, 2010; Fink, 2013).	Defining and describing the skills to be acquired through the game.
2. Rules	Game genre, roles, strategy, actions, reflection, simulation, etc (Yessad et al., 2010; Garris et al., 2002; Bellotti et al., 2013).	Defining the main restrictions of the game and the player.
3. Interactions & Communications	Communication and interaction with the (serious) game (Prensky, 2001; Marsh& Nardi,2014).	Defining the actions of interaction and communication with the application. These actions have to be intuitive and easy to handle.
4. Assessment	Feedback (Whyte et al., 2015; Ryan & Weinstein, 2009).	Providing information on how the players are doing and enabling tracking of their learning activities.
	Assessment Performance (Yusoff et al., 2010; Sørensen & Meyer, 2007).	Evaluating the player’s performance throughout the learning process.
	Progress Performance (Zaibon& Shiratuddin, 2010; Wilson et al., 2009; Graham& Schofield, 2018).	Informing players about their level of performance.
5. Goals	Tasks, goals, levels, challenge (Sørensen & Meyer, 2007; Yessad et al., 2010; Wilson et al., 2009; Dörner et al., 2016; Laamarti et al., 2014; Martin-Niedecken et al., 2019).	Ensuring that the players are achieving a specific goal or skill.
6. Adaptation	Adjustability to player skills (Sobrinho et al., 2015; Adcock & Van Eck, 2012; Ifenthaler et al., 2012; Csikszentmihalyi, 1990; Crockett, 2016; Prensky, 2001; Kickmeier-Rust et al., 2008).	Describing a player-specific learning behaviour and ability.
	Challenging difficulty (Garris et al., 2002; Cox et al., 2012; Jennett et al., 2008; Charles et al., 2011; Lomas et al., 2013).	Adjusting the difficulty of tasks according to the player’s ability.
7. Representation	Media Component (Torrente et al., 2009; Morales et al., 2006; Ravyse et al., 2017).	Providing a visually appealing user interface and appropriate sound effects helps maintain the motivation of the gameplay.
	User Profile (Wilson et al., 2009; Annetta 2010).	It helps identify the player and personalise the game content.
	Object and character (Wilson et al., 2009; Annetta 2010).	Interaction with the game objects and the character.

## 2.2 Rules

This category defines the serious game's and the player's restrictions, shaping the game mechanics. It plays a crucial role by determining which actions are permitted, how task objectives can be achieved, and how players engage in tasks. Additionally, it outlines the gameplay characteristics, including available actions, strategies, and reflection. Based on this, the following requirement is specified:

FR5: The design of a serious game must adhere to a set of game rules.

### **2.3 Interactions and Communications**

This category focuses on how components, players, and the game interact. It defines how initial communications are established, how player actions are handled, and how learning components are linked to gameplay. Based on this, the following requirement is identified:

FR6: A serious game should enable communication and interaction with other components and/or players (in the case of multi-player games).

### **2.4 Assessment**

It summarizes the core components related to assessment in serious games, which are crucial for evaluating effectiveness and supporting player learning. Players should be challenged, receive information to orient themselves, and get feedback on their progress. Assessment plays a key role in improving games, helping players achieve learning objectives through evaluation and feedback mechanisms.

*Feedback:* Serious games must provide immediate or delayed feedback on player performance to guide learning and maintain motivation, this leads to.

FR7: In a serious game, there should be the capability to offer feedback on the user's behaviour.

FR8: A serious game should offer the ability to display information.

*Assessment Performance:* Evaluating players' actions throughout the game enables planning and strategy adjustments to improve learning outcomes.

*Progress Performance:* Displaying player progress (e.g., through scores or achievements) assesses learning, motivates players, and strengthens engagement.

FR9: Serious games must have an assessment component.

### **2.5 Goal**

This category addresses how serious games define tasks, goals, and levels. Tasks should present clear, solvable problems that players can handle using their knowledge and skills. Serious games must also establish specific, transparent goals that players can perceive and achieve. Players should always know what actions are needed to complete tasks or exercises. Tasks often begin with simpler challenges and may be organized into levels, each with a set of predefined goals to guide progression and learning. The following functional requirements are derived:

FR10: A serious game has to include tasks that can be solved.

FR11: A serious game should have clear and understandable goals.

### **2.6 Adaptation**

Serious games must allow learning content tailored to players' backgrounds, needs, and goals. Most serious games use some form of player evaluation, such as scores, to guide in-game adaptation, but stealth evaluation methods can provide even more precise adjustments. To optimize user experience, games must balance task difficulty with player skill levels, maintaining engagement through a state of flow, where challenges match abilities.

*Adjustability to player skills:* Games should be easy to learn but challenging to master, gradually increasing complexity as player skills improve.

FR12: A serious game must have an adaptive component to measure the performance of players' learning progress, thus adapting the game to the ability and the current skill level of players.

*Challenging difficulty;* Adaptivity also involves adjusting players' learning behaviors and knowledge levels to maintain challenge and motivation. The following functional requirement is defined:

FR13: A serious game should have various levels of difficulty in solving tasks.

### **2.7 Representation**

This category focuses on how information is presented within the game. Serious games, distinct from other games, rely on content-specific elements that require high levels of player motivation and engagement.

*Media Component:* To enhance immersion, serious games should feature visually appealing graphics and appropriate sound effects, fostering a stronger sense of presence and greater motivation to succeed. The following functional requirement is defined:

FR14: A serious game should have the ability to display at least videos or to play audio.

*Player Profile:* This component manages the player's identity, enabling interaction, content customization, synchronization, and persistence across different games and learning settings. A well-designed player profile fosters a personal connection, motivating players to engage with the game. Requirement derived from this:

FR15: A serious game should have a user profile component to identify the player.

*Objects and Characters:* Serious games should allow players to interact with objects and non-playing characters (NPCs), which can hold information or provide objectives related to the game's learning domain. This enhances exploration and engagement, offering insight into the real world without real-world consequences. The functional requirement derived is:

FR16: In a serious game, there should be both objects and characters, allowing players to interact with them.

### 3. The Conceptual Framework of Serious Game

The conceptual framework developed in this research supports the design of both the structural aspects and behavioural dynamics of serious games, while also enhancing the overall user experience. Its components were derived from the functional requirements identified in Section 2, through a systematic analysis to ensure that every element contributes to fulfilling these requirements.

#### 3.1 Serious Games Structure Model Components

The conceptual model of the serious game structure describes how the game is built and defines the role of each component in achieving the intended educational objectives. It contains the game world's layout, including characters, objects, and the mechanisms of player interaction. Table 2 presents the model components, linking each to its corresponding requirement and a brief description.

**Table 2: The serious games structure components**

Model Components		Derived from requirements #	Component Description
The Game-Root		No derivation needed	It plays a special role as the origin point for all other game components.
Instructional Content		FR2, FR4, FR5, FR10, FR11.	It is defined in terms of learning outcomes for the game that describe what knowledge and skills the player is expected to achieve or the subject matter that the player is required to achieve.
Player Profile		FR14, FR15	It identifies the players within the game.
Learning Motivation		FR9	These two components are highly preferable for learning environments and increase the attractiveness of serious games.
Repetition		FR2	
UI Manager	GUI Manager	FR8	It is used to display all the required information to players during gameplay. It allows audio and video playback within the game and other effects, and enables the display of GUI elements.
	Media Manager	FR14	
Objects& Character		FR15, FR3	It includes the presence of any particular objects and characters in the game world with which the player can interact with or which are used as decoration.
Reward Manager		FR9	It handles the assessment and measurement of user performance, including managing achievements and rewards. To encourage continued gameplay, strong learning performance should be rewarded.
Feedback		FR7	It manages the feedback given to the player.
Game Mechanics		FR1, FR6	It determines the type or category of gameplay and constrains the possible behaviour by describing players' actions to achieve the game objectives. It allows building methods and rules for players to interact.
Challenge, Level, Learning Outcomes		FR2, FR12	The challenge component represents a specific goal that the players should achieve, integrating problem-solving strategies and increasing their self-efficacy in case of success. The level component represents a series of smaller tasks related to the game's learning objectives, challenges, and tasks.

### 3.2 Dynamic Behavioural Model Components

It defines how the game responds to player actions, handles events during gameplay, and ensures the intended functionality. It also specifies how player actions are assessed and how the game adapts based on assessment results. The components derived from the identified functional requirements are presented in Table 3.

**Table 3: The dynamic behaviour components**

Model-Components	Derived from requirements #	Component Description
UI-Manager	FR8	It displays all the information players need throughout the gameplay.
States	No Derivation Need	It describes the initial state of a game or model
Activity (Actions)	FR3, FR10	It describes the mechanism that enables the player to interact with the game.
Event	No Derivation need	Define the interaction that occurs during the gameplay
Assessment (Task)	FR7, FR9	It represents various tasks, such as multiple-choice questions. It also evaluates the player's outcome and initiates processes to provide the player with feedback and achievements.
Adaption	FR11, FR12	It enables the monitoring of the learning progress of a player and adjusts the learning content and difficulty to match the player's skill level.

### 3.3 User Experience within Serious Games Environment

User experience is critical in serious games as it encompasses players' immediate reactions, emotions, and interactions with the game, which ultimately influence its effectiveness in achieving its intended learning goals (Hassenzahl & Tractinsky, 2006). It also helps the development team identify and evaluate the necessary aspects and components to create an effective serious game. This research identified three key elements that enhance it in serious games: learning, entertainment, and motivation. These aspects are grounded in established literature and provide a concrete framework for evaluating and designing serious games (Connolly et al., 2012; Arnab et al., 2015).

The learning component focuses on achieving the educational objectives of the game. It is characterized by learning mechanics such as questions and answers, tasks or actions, and opportunities for repetition and reflection (Gee, 2003; Kiili, 2005). This helps ensure that the game effectively supports knowledge acquisition and skill development. The entertainment component ensures the game remains engaging and enjoyable by integrating mechanics like rules, challenges, and interactive elements that align with the learning objectives (Sweetser & Wyeth, 2005). A well-designed serious game balances entertainment and education to maintain player engagement without undermining the learning experience (Ryan et al., 2006). The motivation component encompasses elements that entice players to continue engaging with the game, leveraging intrinsic motivators like compelling narratives and meaningful challenges, and extrinsic motivators such as rewards, feedback, and progress tracking (Deterding et al., 2011). Maintaining motivation is essential for sustaining player interest and ensuring the effective delivery of both learning and entertainment aspects.

To positively influence the learning process, a serious game must integrate learning, entertainment, and motivation aspects in a cohesive manner. For example, the game should offer a dynamic, fast-paced experience with adjustable components to accommodate varying player preferences and skill levels. It should also promote rich, affect-driven interactions by aligning the game context with player input, creating an immersive and meaningful experience (Nacke et al., 2010).

## 4. The Applicability of the Proposed Framework

To demonstrate the applicability and feasibility of developing serious games for learning using our proposed framework, we first applied it to redesign the existing serious game 'Senior PM Game'. It is a simple simulation game aimed at teaching project management to university students. Next, we utilized the framework in developing a serious game as a web application for teaching children's 'Learning Kids App'. It contains a list of games to teach children different skills. For example, it includes an 'Alphabetic game' for learning letters, numbers, and simple word writing; 'Arithmetic games' to learn basic calculations with addition and subtraction equations; and 'Memory Game' featuring letters, numbers, and animals. The use of a 'memory game' can help children activate their brains and prevent them from losing their cognitive response, thus improving their memory. In the following sections, we describe the design of these two serious games, aligned with our

proposed framework, and outline the steps that guide the development team in applying the framework to game design.

To effectively apply the conceptual framework in serious game design while ensuring proper integration of learning elements, we propose a structured development process consisting of three key steps:

- Conceptualization: Define the game's core concepts to establish a multidimensional perspective that aligns with learning objectives.
- Sequencing: Organize and structure key game components to create a coherent game sequence that supports the educational goals.
- Implementation: Group related actions and goals by type and corresponding components within the game sequence.

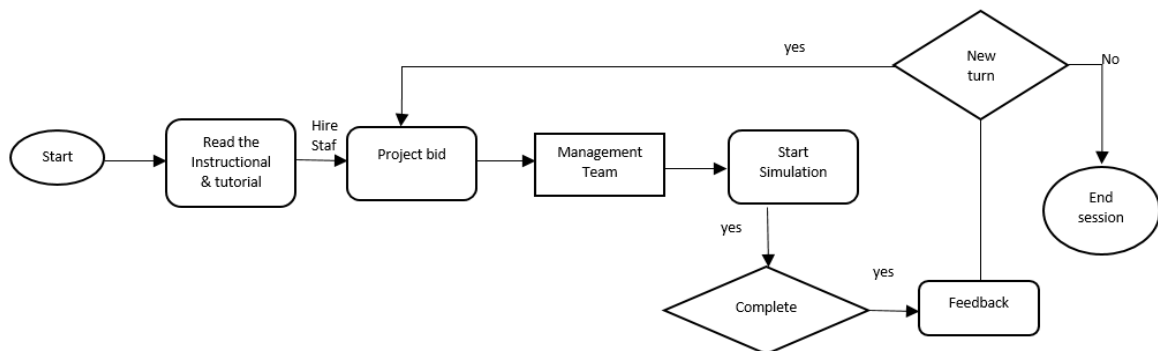
This approach aims to provide a clear reference for understanding interconnections between game elements and to systematically translate high-level learning objectives into concrete, gameplay-integrated components.

a) *The design of Senior PM Game:* The game is designed to teach the principles of project management, emphasizing the importance of effective task assignment for project success. It allows players to enhance their management skills by simulating real-world decision-making scenarios. Players are tasked with completing various project phases and evaluating how well their chosen employees perform. After each project, players receive feedback on key metrics such as completion time, cash flow, and overall project success.

At the beginning, the player selects four employees with different skills. Using this team, the player completes projects that require various combinations of skills. The objective is to maximize the score through effective resource allocation and project execution.

Following the design step, the design process begins with the multidisciplinary team describing the game concepts. They discuss the game objective, target audience, and the learning aspect. In the case of *Senior PM*, the primary objective is to enhance management skills in an engaging and interactive way. The player must strategically assign employees to project tasks, aiming to complete each project within set time and budget constraints. The educational focus is on improving decision-making in resource allocation based on team members' varied skills.

The second design step involves representing the game sequence, which helps identify the main game components; Figure 1 illustrates the game sequence of Senior PM.



**Figure 1: The game sequence of the Senior PM game**

The third step is the implementation description, which organizes actions and goals according to their corresponding game components. This step provides a detailed explanation of each module or block in the game, describing the events that occur during each stage of gameplay. Table 4 presents these details, outlining how individual components function and contribute to the overall game experience.

**Table 4: The Senior PM game components**

Components	Description
Character & object component	Choose employees: The player chooses four employees to interact with.
UI Manager	Provide a short tutorial and instructions explaining the game's basic objectives and rules.

Components	Description
Feedback	To show interface tips and information, provide Feedback after completing any project if the player successfully completes their task within the time and the cash flow.
Project bid (Challenge/Task, reward, repetition)	It has learning components like challenges, tasks, rewards, etc. In the game, a player's task is to select or fire employees to have the best team to manage and complete the projects successfully. The reward is to get a better score and earn money.
Player Profile	Save score: Recording the points earned during each play.
Learning Outcome	Effective allocation of tasks for varying employees. The goal of the game is to make the right choice in allocating the employees who have different abilities and skills.
End of session	After completing all tasks, the player is invited to play again or to exit the game

B) *The design of the Learning Kids App*: The Learning Kids App is a container for multiple educational mini-games, developed using Vue.js. Figure 2 displays screenshots of this game, including: (a) the main screen, (b) an alphabet and numbers game for learning letters and numbers, and (c) a word learning game. Players can choose which game to play, with the core interaction involving dragging visual elements, representing a letter or number, and placing them in the correct position. Once placed, the game provides immediate audio feedback indicating whether the selection is correct.



**Figure 2: Learning Kids App**

The design of this game follows our conceptual framework, incorporating various components such as game mechanics, a UI manager for audio feedback, a reward manager for score calculation, instructional content, and a challenge module that manages the sub-games. Each sub-game is structured with multiple levels to support progressive learning. Additionally, interactive objects and animated characters are used to increase engagement and promote sustained attention.

## 5. Conclusion

This research presented a structured approach to the design and development of serious games for learning. It emphasized the integration of educational, entertainment, and motivational elements to enhance the user experience and learning outcomes. By defining functional requirements and mapping them to specific serious game components, the framework provides a practical guide for the development team to align educational goals with engaging gameplay mechanics. The implementation of the Learning Kids app and the redesign of an existing serious game, the Senior PM game, demonstrate the applicability of this approach in a real-world context. Specifically, it highlights how modular game components (e.g., adaptive challenges, feedback, UI manager, and instructional content) can be cohesively designed to create immersive and educationally

meaningful experiences. Ultimately, this approach facilitates the creation of serious games that are not only educationally effective but also engaging and motivating for diverse groups of learners. It also facilitates collaboration among a multidisciplinary team by providing a common reference for integrating educational and technical requirements. Future work could investigate whether any essential requirements or components are missing from the framework to ensure adaptability and completeness across different contexts. Further evaluations are also needed to assess its practical benefits, such as improving design productivity, as well as to validate its applicability to other game genres.

**Ethical Declaration:** We hereby confirm that this research does not require ethical approval.

**AI Declaration:** No AI tools were used to create this research.

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