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Practical Methodology for the Design of Educational Serious Games

Frutuoso G. M. Silva [1,2]

[1] Department of Computer Science, University of Beira Interior, 6201-001 Covilhã, Portugal; fsilva@di.ubi.pt
[2] Instituto de Telecomunicações, 6201-001 Covilhã, Portugal

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Abstract: Educational serious games are primarily intended to teach about or train on a subject. However, a serious game must also be catchy for the player to want to play it multiple times and thus learn while playing. The design of educational serious games includes game experts and pedagogical experts that must be able to efficiently communicate to produce a product that is both educationally efficient and fun to play. Although there are some design frameworks to help with this communication, they are usually more conceptual and do not distinguish the fun factor from the learning contents well, making communication difficult. In this paper, a new practical methodology is presented to support the design process of this kind of digital games. This methodology is more all-encompassing because it identifies all the main steps that are needed to define the learning mechanisms in an educational serious game, from topic choice to user experience. It also separates the game's learning contents from other mechanics used to keep the game fun to play. Finally, some practical examples are shown, illustrating the use of this methodology.

Keywords: educational-game design; design methodology; educational serious games; games-based learning; serious games for learning

1. Introduction

Nowadays, games are part of our culture and lives, and are used mainly for entertainment. People play games to escape the real world, work or school, and its social norms [1]. They value the sensations from doing new things, and trying new challenges, strategies for problem solving, and participating in social experiences. Lindley [2] proposed a game taxonomy that distinguishes between game forms and functions on the basis of narrative, repetitive gameplay, and simulation, beyond other classification dimensions, from virtual to physical gaming, and from fictional to nonfictional gaming. There is therefore a wide range of game types, which make the design process complex. However, there are games explicitly produced for reasons beyond entertainment, i.e., serious games [3]. Serious games are not purely designed for entertainment, but to accomplish something meaningful in the real world [4]. For example, exergames are a type of game with real-world meaning because they promote physical exercise [5,6]. Nevertheless, Botte et al. [7] proposed a taxonomy that defines three types of serious games. First, role-playing games without obligatory simulating situations borrowed from reality. Second, business games in which the simulation is like a reality model that includes aspects of those games. Third, games simulating reality in all its aspects. Currently, serious games are an important tool in several areas like health, education, and industry because they facilitate the learning and training process by engaging the user and increasing their motivation. They are particularly very useful in education because they promote the participation of students in the learning process when compared to traditional teaching methods. Students use new technologies on a daily basis to communicate, access social networks, and play games, but these technologies are normally not involved in the learning process. However, there are several studies that demonstrate the benefits

of serious games in learning [3,8–11]. The success of serious games for learning and training has turned video games into a good learning method, associated with new technologies. For example, Baptista et al. [12] described the relationship between game categories and skill development using serious games. However, the process of designing a serious game for learning is not easy because it involves several professionals, such as game designers, programmers, and experts in the topic to learn. Sometimes, communication between these professionals is not simple because they use a different vocabulary and have different perspectives on the game. For example, a game designer wants to create a fun experience, while experts are more focused on creating a learning tool. However, according to Zyda [13], pedagogy must be subordinate to the story, i.e., serious game must first be fun, or the player will not want to play it. Zemliansky and Wilcox [14] also referred to the need for a balance between the art and science of game design for learner engagement while keeping learning integral and still creating an enjoyable user experience. One of the mechanisms used in these games to learn/advance is repetition, which allows players/learners to evaluate their performance on the basis of a trial-and-error strategy, and encourages them to persist to complete the tasks. Nevertheless, there are not many specific methodologies/frameworks to design educational games that include all key elements of this type of game and that considers all professionals involved in its development.

There is not a single way to develop an educational serious game because it depends on several factors, like target audience, teaching topic, and game genre. Game genre is determined by the challenges that the player faces and which actions they take to overcome them [15]. However, most proposed methodologies/frameworks to design (serious) games are based on mechanics, dynamics, and experience. Mechanics is associated with the formal rules of the game that are instantiated at playtime and influenced by the player's input, forming dynamics (i.e., the run-time behavior of the game) that creates an experience for the player. However, learning contents cannot only be associated with mechanics, as other mechanisms are needed to support the learning contents. Nevertheless, Barbosa et al. [16] presented a methodology to design and develop serious games that was based on the concept of learning mechanisms that must be included in the game, either in storytelling, gameplay, or mechanics. This paper extends this concept and presents a new methodology to design educational serious games that is more in-depth and that can be easily understood by all the development team. It clearly describes the learning mechanisms that can be incorporated in an educational serious game and the remaining components that are used to make it fun. The applicability of the methodology is illustrated on the basis of previously developed serious games that now contribute to its formalisation.

2. Related Work

There are several studies related to (serious) games, but here we only present those that present methodologies or frameworks for designing (serious) games. However, game design is an iterative process that consists of three steps: design, prototype, and play testing according to Sales and Zimmerman [17]. Similarly, Robson et al. [18] presented a framework of gamification principles that is also a cycle involving mechanics, dynamics, and emotions. As we show below, some of the frameworks for the design of serious games are similar to this one.

Hunicke et al. [19] presented the Mechanics, Dynamics and Aesthetics (MDA) framework, which is a formal approach to understanding games from production to consumption. It breaks games into their distinct components and establishes their design counterparts as part of MDA. Thus, mechanics describes the main components of a game, dynamics its run-time behavior, and aesthetics corresponds to the desirable emotional responses of the player. This framework is general for game design, but it is not enough to help the design of serious games by itself.

Amory [20] introduced a theoretical framework for educational-game development. He extended the original game object model (GOM) to include a new social space object and called it GOM version II. This framework considers that an educational game consists of a set of components (objects), each of which is described by an abstract and concrete interface. The pedagogical and theoretical constructs are associated with the abstract interface, while the design elements are associated with the concrete

interface. However, this framework is based on the object-oriented programming paradigm that makes it too theoretical and not easy to understand for team members that are not programmers.

Winn [21] presented the (Design–Play–Experience) DPE framework for the design of serious games for learning as an expansion of the MDA framework. It described the relationship between designer and player, where the designer Designs the game and the player Plays it, which results in the player's Experience (DPE). Then, to consider learning games, he extended this framework to include four levels for each component (i.e., Design, Play and Experience): Learning, Storytelling, Gameplay, and User Experience. However, this framework is more oriented toward analysis of existing serious games because it defines a uniform language for the team to discuss and critique a game's design. It is also not clear how levels are converted into game elements, making it more difficult to use it in the design process of a game, for example, how a learning level is translated into game elements.

Yusoff et al. [22] introduced a conceptual framework for serious games where they enumerated a list of components that must be considered for learning through a serious game. The diagram of the framework has all the components, where the central component is Learning activity having the learning contents on one side and the game on the other, but how these two components are related is not explained. Thus, this framework does not help in the design process of a serious game.

Schottman et al. [23] presented a seven-step method to design serious games showing the different involved actors and tasks to be accomplished. Most of these steps were also included in our methodology. They also presented a set of multiview tools to help actors cooperate in an efficient way.

Marne et al. [24] described a conceptual framework for serious-game design called the six facets, where the type of expertise is identified for each facet. In addition, they defined a serious-game design-pattern library to help teams solve some design problems and foster communication between stakeholders, using the six-facet framework. Thus, this methodology is useful to understand the role of each expert within the six-facet framework and to facilitate communication between design team members using the design-pattern library. However, it did not properly define a methodology to design a serious game.

Arnab et al. [25] introduced a framework to relate Learning Mechanics with Game Mechanics, called LM–GM. As said by the authors, the framework is not a methodology to design serious games, but more like an analytic tool to study the mechanisms that join the pedagogical and game features. However, it is useful because it gives an overview of learning mechanics and game mechanics that can be incorporated into a serious game.

Carvalho et al. [26] presented a conceptual model to understand the relationships between serious-game components and educational goals. This model utilized the conceptual framework of activity theory to perceive the structure of a serious game called Activity Theory-based Model of Serious Games (ATMSG). In this case, the authors considered three components, i.e., gaming, learning, and instructional components, where each was subdivided into actions, tools, and goals. This model was composed of two phases, activity analysis and action analysis, and it was applied in four steps: identify and describe activities; represent game sequence; identify actions, tools, and objectives; and provide the description of the implementations. Therefore, this model is more useful as an analysis tool than a serious-game design tool.

Roungas [27] introduced a conceptual model of educational serious games where he identified all elements of an educational game and presented a class diagram of such a game. An important aspect of his model is that it related level with learning outcome, i.e., every level required the achievement of learning outcomes. It also presented the web implementation of his model, making it a tool for the design process, and as a way to keep the game-design document (GDD) updated and accessible during the design process. This implementation could also overcome the difficulty of other, nonprogrammer team members to perceive the conceptual model. This model is more detailed, but also more complicated to understand by all team members (i.e., game designers, programmers, and experts).

Lope et al. [28] presented a high-level methodology divided into five phases (i.e., startup, design, production, test, and postproduction), where the design, production, and testing phases were similar to the iterative cycle of the design process of Sales and Zimmerman [17]. In the design phase, they considered a set of key components (e.g., scenario, characters, and educational competences and challenges), and the game structure followed the theater metaphor, which includes the elements of act, scene, action, and dialogue. In addition, they identified the main design tasks and related them to different roles (i.e., project manager, computer analytic designer, client, writer, and educator). However, it was not clear in this methodology how learning contents are translated into the game.

Pesántez et al. [29] did a systematic review of the approaches for serious-game design and identified 11 approaches for designing serious games based on their selection criteria and period. Thus, they identified four phases for the design of a serious game, which are analysis, design, development and evaluation. For each phase they identified a set of factors and some pedagogical and didactic aspects that must be considered into the design of a serious game. But how are these aspects and factors combined to design a serious game?

Recently, Spyridon and Ioannis [30] described a conceptual methodology based on a task repository where one can define task dependencies and the skills required for each task. The main idea was to have an adaptive schema based on an engine with artificial intelligence that would prioritize the next learning tasks according to prior knowledge of the player. Thus, it is not a methodology to help the design of serious games, but a way to create an adaptive scheme for the learning process inside serious games.

Furthermore, other methodologies/frameworks addressed only a specific game genre. For example, Lope et al. [31] described a methodology to support narrative adventure games, where the game was designed on the basis of chapters and scenes; Marchiori et al. [32] introduced a methodology to create point-and-click adventure games; and Moya et al. [33] presented a framework for the design of single-user task-based serious games.

3. Methodology Description

This methodology is based on the practice of serious-games development and takes into consideration other methodologies/frameworks proposed in the literature, such as MDA [19] and DPE [21]. However, our methodology is all-encompassing because it defines all the main steps needed to define the learning mechanisms in an educational serious game. It starts with the choice of topic for the serious game and the learning objectives associated with it, and ends with the user experience, as shown in Figures 1 and 2. Our methodology is described by Figures 1 and 2—the former presents the main game and the latter the additional learning mechanisms. Figure 2 is explained in more detail below. In Figures 1 and 2, all steps represented by a rounded rectangle are related to the learning mechanisms or learning outcomes, while other rectangles are associated with the game's characteristics. Arrows with dashed lines are associated with an iterative cycle where the game designer can redefine mechanics or learning mechanisms to improve user experience or learning outcomes, respectively. The MDA and DPE frameworks are more focused on the definition of game mechanics and dynamics, and on the game's user evaluation/experience. The expanded DPE framework also adds four levels (i.e., Learning, Storytelling, Gameplay and User Experience) to the components, but these levels are not easy to operationalize inside each component.

Figure 1 shows that the first step in our methodology is to define the game topic and learning objectives. It is then necessary to choose an appropriate game genre for the defined topic and learning objectives. To choose game genre, it is also important to consider Bloom's hierarchy of cognition [34], which can be seen in the work of Sherry and Pacheco [35], who related game genres with Bloom's educational objectives, as shown in Table 1. Similarly, Baptista et al. [12] described game genres widely accepted in the video-game industry, and separated action games from adventure games.

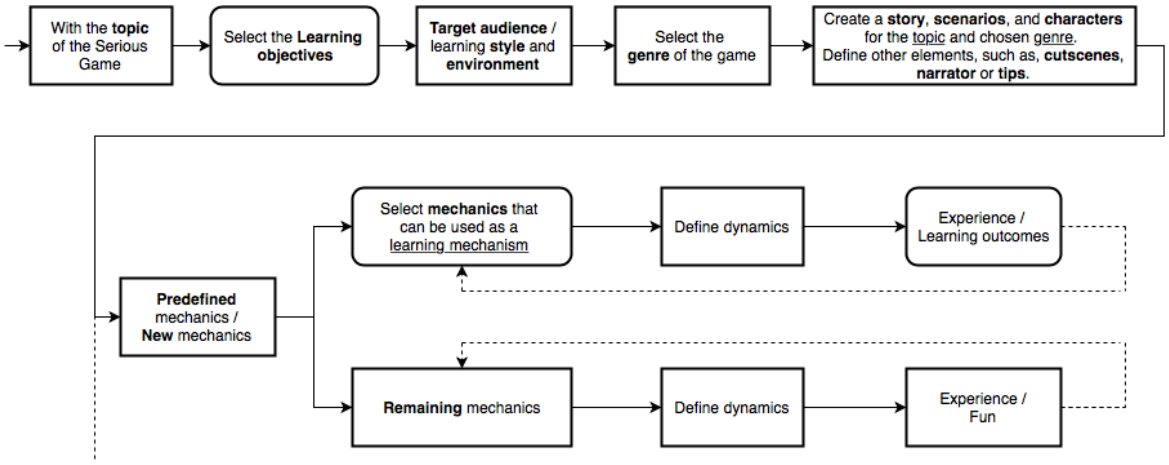

Figure 1. Main steps defining main game.

Table 1. Game genres based on Bloom's educational objectives (adapted from [35]).

	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
1 - Shooters	X	X	X	X	X	X
2 - Action/ Adventure	X	X	X	X	X	X
3 - Fantasy/ Role-Playing	X	X	X	X	X	X
4 - Sports	X	X	X	X	X	X
5 - Simulation	X	X	X	X	X	X
6 - Puzzle	X	X	X	X		
7 - Quiz/Trivia	X					

It is also important to consider the target audience with regard to their age and gender [36], because some genres are more popular for different age groups depending on their learning style [37]. Honey and Mumford [38] identified four distinct styles of learning (i.e., activists, reflectors, theorists, and pragmatists). Activists are people who learn by doing and like to involve themselves in new experiences. Reflectors learn by observing and thinking about the experience, they spend time listening and observing, and tend to be cautious to reach conclusions. Theorists need to understand the theory behind the actions, and they learn on the basis of models, concepts, and facts; they like to investigate and synthesize, and feel uncomfortable with subjective judgments. Finally, pragmatists are keen on trying things out, they are practical, they act quickly and confidently on ideas, and get straight to the point. They search for new ideas that can be applied to the problem at hand. Honey and Mumford suggested that most people tend to follow only one or two of these styles.

Table 2 shows the relationship between learning techniques, learning activities, and game genres taking into account the learning styles. The game genres considered here are the same as in Table 1. Another element that should be taken into account is the learning environment in which a game is used. For example, if the game has to be used in the classroom, it needs to be based on short sessions. It is also important to consider what kind of learning environment we want to create, collaborative or individual. All these aspects must be evaluated to choose game genre.

Table 2. Relationship between learning techniques, learning activities, and game genres (adapted from [37]).

Learning Techniques	Leaning Activities	Game Genres
Practice & feedback	Questions, memorization, association, imitation	2, 4
Learning by doing	Interaction, practice, drill, imitation	1, 2, 3
Learning from mistake	Feedback, problem	3, 6
Discovery learning	Feedback, problem, creative play	1, 2, 6
Task-based learning	Understand principle, graduated tasks	5, 6
Question-led learning	Question, problem	7
Situated learning	Immersion	1, 2, 3, 4, 5
Role playing	Imitation, practice, coaching	1, 2, 3
Constructivist learning	Experimentation, questioning	5
Learning object	Logic, questioning	5
Coaching	Coaching, feedback, questioning	2, 5
Intelligent tutors	Feedback, problem, continuous practice	2, 6

After defining the game genre, it is already possible to create a story for the game, taking into account the topic, learning objectives, target audience, learning environment, and game genre. Tied in with the story are also created scenarios, characters, and other important elements to adequately present the story to the player. For example, the game can have cutscenes to introduce some situations, or a narrator to explain parts of the story or even offer tips to the player. A cutscene is a sequence in a video game that is not interactive, breaking up the gameplay. This kind of element could be used to show conversations between characters, introduce new gameplay elements, show the effects of a player's actions, or foreshadow future events.

Now, one can advance to the design of the game (i.e., defining the mechanics, dynamics, and experience of the player) because learning objectives were defined and a story was developed to support it according to the game genre. Thus, each game genre has a set of predefined mechanics from which to select those that can be used as a learning mechanism, but also new mechanics that could be included in the game. For those mechanics that can serve as a learning mechanism, one can then develop the dynamics to give an experience to the user and transmit some knowledge (i.e., learning outcomes). Dynamics defines the way the player interacts with the mechanics inside the game, and how it can contribute to the user's experience and their learning. For example, a shooter game can serve to develop the theme of viruses in the human body, where the player uses shooting to destroy a virus. So, every time the player destroys a virus, their health increases, or they gain points or skills to advance in the game. Therefore, the learning outcome associated with this shooting mechanic is that killing viruses is good for health.

However, other mechanics that cannot be used as learning mechanisms must be used to keep the game amusing and engage the player. Otherwise, the game could defraud the user's expectations. Thus, for those mechanics, one must develop dynamics to offer a fun experience to the user.

Nevertheless, it is often not enough to use mechanics as learning mechanisms. In these circumstances, one can add new layers to the game to support the learning process (see Figure 2). Figure 2 completes the diagram of Figure 1 with the possibility to add learning layers to the main game, for example, through minigames. Minigames could be puzzles or quiz/trivia. If the goal is for players to learn on the basis of knowledge, comprehension, application, and analysis, according to Bloom's hierarchy, then a puzzle is adequate. However, if you only want to test the user's knowledge, trivia/a quiz is the right choice. Minigames can fit well in Bloom's hierarchy and in player learning styles.

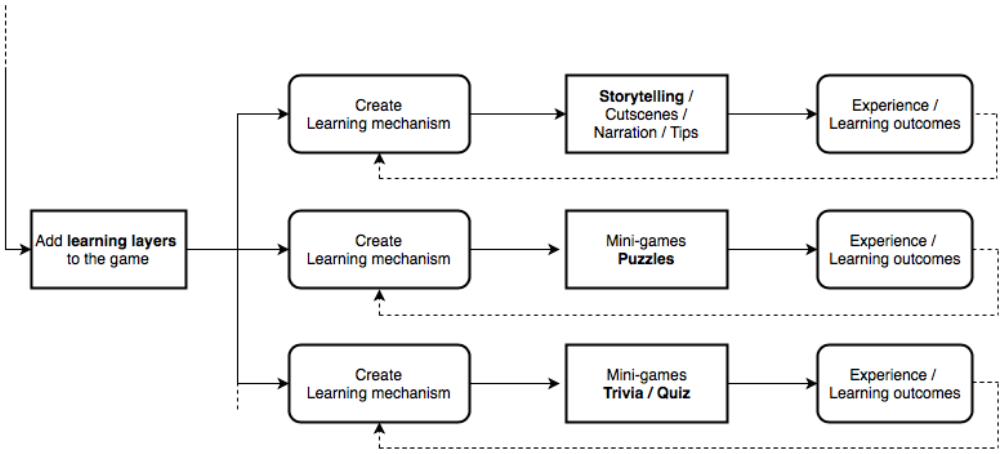

Figure 2. Learning layers that could be added to main game.

Another way to create learning mechanisms is through the story(telling) of the game, for example, using cutscenes, narration, or tips as a way to more clearly present the story and introduce facts or situations that must be known and analyzed by the player. Storytelling is also a good way to keep the player's interest to discover the story's outcome.

The game-design process is, of course, iterative [17], where we have a cycle with design, prototyping, and play-testing. Thus, Figures 1 and 2 show this iterative process represented by arrows with dashed lines. With this methodology, one can identify all elements of a serious game where learning mechanisms can be incorporated, making the game-design task easier. To better understand this methodology, some practical examples are now described to explain the four possibilities to design learning mechanisms in an educational serious game.

First, one can use mechanics as a way to support learning content. For example, Aparício and Silva [39] created a game to train the main math operations inspired by the Flappy Bird game, where the player has to keep the bird flying but at the same time they can catch items like coins, numbers, or operators. The numbers and operators are used to perform mathematical operations and advance in the game, and the coins are used as a way to motivate the player because they can be used to buy items to personalize the bird/character. Thus, catching mechanics is used to collect the math operators and numbers involved in the mathematical operation, as well as the result of the operation (i.e., learning by doing, but also question-led learning). If the player correctly solves a set of operations, they advance to the next level of the game with another operator. There are four operators available (i.e., +, -, *, and /) combined into different levels. The other mechanics to keep the bird flying and avoid obstacles is used in the same way as in the Flappy Bird game. This strategy maintains the fun of the game, which allows users to replay it several times just for fun. Still, each time users plays the game, they learn because they need to perform operations in order to progress. Barbosa and Silva [40] also developed a game about the human body's circulatory system, where different blood components are considered (i.e., red blood cells, white blood cells, platelets, and also bacteria). In this game, the player uses red blood cells to catch oxygen to spread it in the circulatory system, avoiding the bacteria. It is a real-time strategy game, where its mechanics are used as learning mechanisms. Catching oxygen, using platelets to repair red blood cells, and fighting bacteria are essential actions to complete the mission of placing oxygen inside the bloodstream (i.e., using role-playing and learning by doing).

Second, one can incorporate learning contents into minigames as a new learning layer of the game. When learning outcomes require memorization, one can incorporate that in puzzles or arcade games. These types of games challenge players with puzzles based on repetitive tasks (i.e., discovery learning and learning from mistakes). For example, Barbosa et al. [16] presented a minigame to separate garbage collected by the player, where the idea is to associate the type of garbage with the right color (i.e., blue for paper, yellow for metal, green for glass, and red for plastic). Furthermore, this game is played using the Xbox controller, where Xbox buttons have the same colors to reinforce the idea of separating

garbage by its type. In this game, all levels include a minigame as a learning mechanism and a way to complement the learning process inside the game (i.e., task-based learning).

Third, if the idea is to test the knowledge of the player, then a quiz/trivia minigame is the best choice. It can evaluate the mastery of a subject on the basis of a question-and-answer format because it requires information memorization. For example, Lopes et al. [41] developed a serious game to teach concepts of cybersecurity to teenagers. It is a detective game where the player takes the role of a detective to investigate cybercrime of ransomware in the first level. The game starts with a cutscene that presents a teen using their smartphone trying to buy a pair of sneakers online, and after downloading an application suggested on the website, his mobile phone is locked. Thus, he decides to seek help from the police, where the detective tries to solve the problem. As the detective, the player has to solve several minigames about sharing information in social networks, phishing, and the importance of creating strong passwords. In these minigames, the player makes decisions and learns on that basis, i.e., at the end of each minigame, each decision is explained to the player regardless of the choice being correct or incorrect (i.e., learning from mistake). This way, the player is always informed of the various situations that could occur on the basis of their online behavior and decisions. In this game, to support the learning mechanisms related to each topic (i.e., sharing information in social networks, phishing, and creating strong passwords), a layer was created for each minigame. However, the main idea of the game remains the same: the detective must go to several investigation rooms to solve the cybercrime (i.e., role-playing), where each investigation room includes information and a minigame (i.e., using question-led learning) associated with the topic.

Fourth, one can incorporate the learning contents in storytelling by using cutscenes to introduce relevant information to the player, as was the case of the game described in [41], where the cybercrime is introduced using a 3D cutscene. Other ways are available too, such as with the use of a narrator or by showing tips to the player based on the context of the game (i.e., using intelligent tutors).

Those are the four ways to create learning mechanisms inside an educational serious game that help the game-design team to more easily communicate during the design process. However, one can design a serious game that could include more that one or even all of these four situations.

4. Discussion

The design of an educational serious game is a complex process because it must fit the learning objectives and be fun at the same time to achieve the desired pedagogical goals. Thereby, a multidisciplinary team is required to design this kind of game, which includes at least game designers and developers, and pedagogical experts. Nevertheless, there are several learning styles and game genres [37], which make it more difficult to design a serious game because it can work for some players but not for others. Thus, the choice of game genre must be done taking into consideration the target audience and their learning style. For example, shooter games encourage the exploration of a scenario, and finding objects and interacting with them or with other players. In role-playing and adventure games, the player needs to gain knowledge, power, and skills to advance, overcome enemies, and solve puzzles. However, these games require knowledge, comprehension, and application to proceed, which can be used for learning purposes (see [35] for details about how game genres match learning outcomes).

The proposed methodology identifies all main steps in the design of an educational game, from topic definition to user experience (i.e., from beginning to end). It allows the identification of game components that support the learning process and those that are only used to keep gameplay enjoyable and addictive. Thus, it helps game designers to more easily communicate with developers and pedagogical experts.

Some of the previous frameworks (e.g., MDA [19] and DPE [21]) were created to analyze games and not necessarily design them. These frameworks do not specifically address aspects of game design beyond gameplay, for example, they do not include aspects such as storytelling or game genre. DPE [21] was extended to support educational serious games by including four levels: Learning,

Storytelling, Gameplay, and User Experience. However, how these layers are used to design a game is not easy to understand. For example, Winn [21] said: 'In the learning layer, the designer designs the contents and pedagogy, which results (hopefully) in teaching when the player plays the game'. However, how are contents and pedagogy inserted into a game? Its terminology builds on different disciplines that make up serious-game design; thus, it is more useful to discuss and critique game design than to actually design a game.

Most frameworks for educational serious games do not explain how learning contents can be inserted into a game. Normally, they only present a list of components [22], learning and game mechanics [25], the game's several facets [24], or the activities of the system [26], but they do not explain how these aspects work together to create an educational game because most of them are more oriented toward analysis purposes. For example, Lope et al. [28] used the theater metaphor in their framework, which is more appropriate for the development of educational adventure games. Other frameworks use language that is more related to computer science [20,27], making them too complex to be used for game designers or pedagogical experts. Moreover, other methodologies only address one game genre, such as [31–33], making them too specific. In our methodology, on the other hand, we created a flowchart with the main steps to design an educational serious game that defined how the learning and entertainment mechanisms could be created in the game. Therefore, our methodology can be viewed as a process to create an educational serious game that is easily understood by the design team; the collaboration of pedagogical experts is assigned to tasks represented by rounded rectangles.

Nevertheless, there is a game genre that does not fit well in our methodology due to its specificities, i.e., simulation games that simulate reality, because this kind of game has its own rules according to the system that it wants to mimic. Thus, most of the mechanics are associated with those rules, and learning occurs on the basis of using the rules of the system (i.e., on the basis constructive learning and learning objects).

This paper did not consider issues related to the assessment of serious games, but All et al. [42] summarized the best practices to evaluate the effectiveness of digital game-based learning, where they referred the use of control groups, and similar test pre- and postintervention to evaluate pre-existing differences. Petri and Wangenheim [43] also evaluated the state of the art on how educational games are evaluated, and they presented similar results. Thus, assessment out of the game can be done according to the best practices, as mentioned by these authors. Assessment in the game was considered by our methodology because one can add a new learning layer to the game with quiz/trivia for this purpose. Assessment in the game can also be associated with points, levels, or badges.

A preliminary evaluation of the methodology was done with a group of master's students divided into six groups, five with three people from different areas, and another with only two people. (e.g., computer science, arts, cinema, or game design), which proposed an exercise to design an educational serious game using this methodology. After this exercise, all elements of the group evaluated the methodology through a questionnaire with balanced responses using a five-point Likert scale. Most students agreed with the statement that the methodology was useful in the development of educational games, as shown in the left graph of Figure 3. When questioned if the methodology helped communication between members of the design team, the answers were also positive but, in this case, a few students disagreed (i.e., five out of 17, as shown in the right graph of Figure 3).

However, most of them considered the methodology useful because it specified the main steps through which to create an educational game, and separated learning mechanisms from entertainment mechanics, as shown in the graphs of Figure 4. Initially, the methodology was described by a single diagram, and most of the students (i.e., 10 out of 17) considered it a little complex. The questionnaire included an open question where students could suggest improvements to the methodology. In this case, most of them suggested the simplification of the diagram. On that basis, two diagrams were created, one to specify the main game and the second to specify the learning layers that could be added to the main game, making it easier for them to understand.

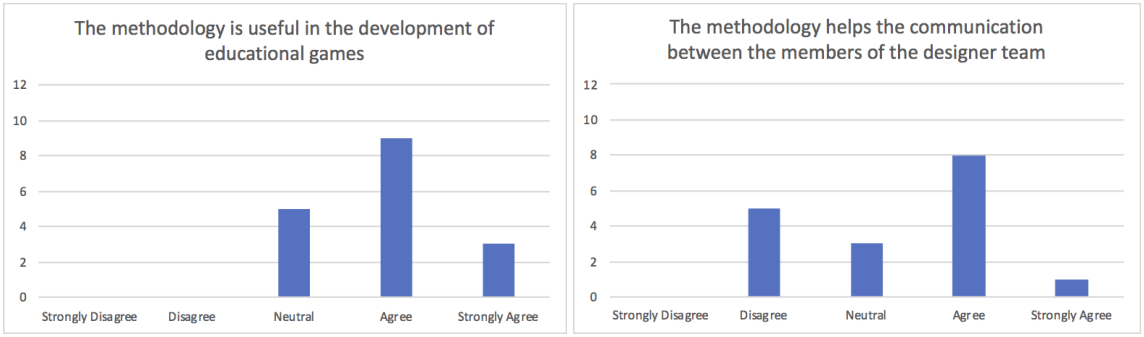

Figure 3. Answer graph about methodology: (**left**) Is it useful in the development of educational games? (**right**) Does it help communication between design-team members?

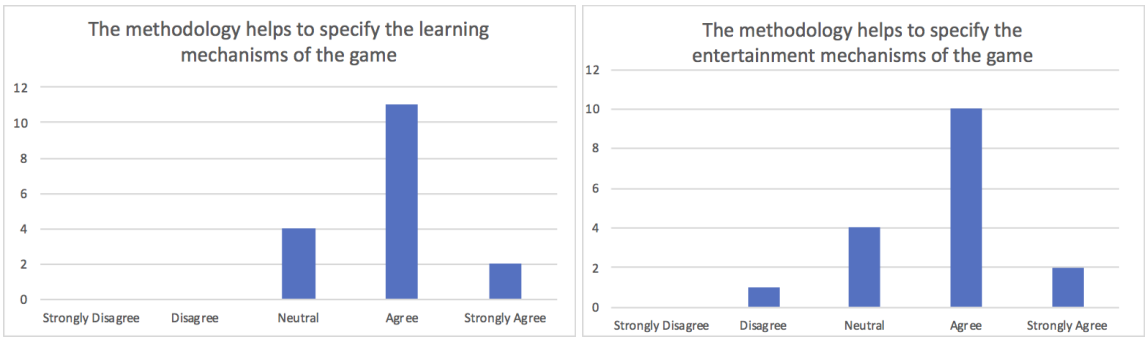

Figure 4. Answer graph about methodology: (**left**) Does it help to specify game learning mechanisms? (**right**) Does it help to specify game entertainment mechanisms?

In short, the methodology identified all situations where learning mechanisms could be created and its relationship with game components, which facilitated and improved communication within the design team. So, this simple methodology could help in designing better educational serious games because it clearly defines the learning and entertainment mechanisms inside the game.

5. Conclusions

A practical methodology to design educational serious games was presented to facilitate communication between design-team members. It identified the possible mechanisms for learning that could be incorporated in the game to help the design process. This methodology makes a distinction between mechanics that are used as learning mechanisms and those that are only associated with gameplay to keep the game fun and addictive. It also defined new learning layers that could be added to the main game, for example, through the use of minigames. Therefore, this methodology was developed on the basis of the experience of the development of educational serious games from several genres, which shows its versatility and usefulness. It could also be more easily understood by members of the design team because it uses simple vocabulary and diagrams, which identify the four possibilities to create learning mechanisms inside the game beyond entertainment mechanisms.

In the future, we hope to analyze a set of serious games on the basis of our methodology to verify if more learning mechanisms that were not considered by the methodology exist. We also intend to develop a hands-on assessment of the methodology with game-design and -development master's degree students and pedagogical experts, creating various multidisciplinary groups and asking them to design a serious game using our methodology. In the end, we aim to ask them to evaluate the methodology to identify what its strengths and weaknesses were. The idea is to evaluate these results according to their role, i.e., evaluate what game designers, game developers, and pedagogical experts have to say about the methodology.

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