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Article

Evolution of an Adaptive Serious Games Framework Using the Design Science Research Methodology

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Abstract: Games with purposes beyond entertainment, the so-called serious games, have been useful tools in professional training, especially in engaging participants. However, their evaluation and, also, their adaptable characteristics to different scenarios, audiences and contexts remain challenges. This paper examines the application of serious games in professional training, their results and adaptable ways to achieve certain goals. Using the Design Science Research (DSR) methodology, a framework was built to develop and evaluate serious games to improve user experience, learning outcomes, knowledge transfer to work situations, and the application of the skills practised in the game in real professional settings. At this stage, the investigation presents a framework regarding the triangulation of data collected from a systematic literature review, focus groups and interviews. Following the DSR methodology, the next steps of this investigation, listed at the end of the paper, are the demonstration of the framework in serious game development and the evaluation and validation of this artefact.

Keywords: Framework; Adaptive; Serious Games; Professional Training; Learning Outcomes

1. Introduction

Serious games, also called games with a purpose, are games that have purposes beyond entertainment itself.

These artefacts have been used in various applications, such as in education and professional training.

In professional training, these games are used in areas such as the Military [16] [14] [12], Telecommunications [1], General businesses [10] [19] [34] [3], Healthcare [37], Manufacturing companies [29], Hospitality [26], and Finance [21].

As games, these artefacts should provide fun, cited by [13] as one of the most important characteristics of serious games. They should also be effective for learning but, as [25] points out, although there is empirical evidence on the contribution of serious games to learning, more research is still needed on their contribution in this matter.

Currently, serious games have two major challenges regarding their use in the teaching-learning process: To have their results evaluated in a way that is coherent with learning; and to be adaptable to different contexts, audiences, and moments of the players.

Regarding adaptation, to maintain the player's focus on an in-game learning task, [24] argue that dynamic game adjustment is important to provide both a challenging and fun experience and effective learning, to prevent tasks from being too easy or difficult.

Moreover, the lack of adaptability of games can result, as [22] pointed out, the loss of efficiency in learning if users perceive the game’s dynamics and evolve without achieving the learning objectives. This lack may also result in the impossibility of repeating the application of the game for the same users once they already know its content.

So, the motivation for this research was to improve the teaching-learning process in professional training by using serious games efficiently.

This article is one of the results of an investigation on Serious Games, called Influence of adaptability of Serious Games on learning outcomes and the application of knowledge and skills in professional training, and is related to the developed artefact in this investigation.

To describe the activities carried out in this investigation and report on the next activities to be developed, this paper first presents the objective and research questions, followed by the methodology used in this research and the description of the activities carried out so far. The proposed framework is described in the next section, with its dimensions and relevant aspects.

This paper presents a comprehensive evolution of a conceptual framework for the design of adaptive Serious Games grounded in the Design Science Research (DSR) methodology.

The framework's second version was first introduced at the 2023 Iberian Conference on Information Systems and Technologies [40], where it emerged from a systematic literature review focused on adaptive elements in Serious Games and their underlying design principles, and from triangulation with focus groups and expert interviews.

Since then, the framework has undergone a third iteration. This version was developed after applying the framework to guide the design, development, and evaluation of a complete Serious Game called “*Encontrando Tempo*” (“Finding Time” in English), thereby incorporating experimental validation in professional training settings.

These three versions reflect a coherent research programme that culminated in the defence of the author's doctoral thesis [41] and were disseminated through peer-reviewed

outputs, including a journal article in Computer Applications in Engineering Education [42] and book chapters [43] [44].

2. Objective And Research Questions

This investigation objective is to propose a decision framework concerning the adaptation of serious game elements in the professional training context. That is, a framework for improving:

- The player's experience and involvement in the game;
- The learning outcomes;
- The transfer of knowledge to work situations;
- Application of skills practised in the game in real-life scenarios during professional activities.

To reach this objective, three research questions were formulated:

1. What is the influence of the game elements?
2. How should the game elements be adapted?
3. How to classify and organize the game elements to adapt and meet the previously established objective?

3. Methodology

The methodology chosen for this investigation was Design Science Research - DSR as it involves the development of an artefact and, as pointed out by [11], this methodology has the characteristic of investigating how things should be, not how things are or behave.

The process sequence of the model presented by [27] for DSR was adopted to conduct this investigation:

1. Identify the problem and motivate;
2. Define the objectives of a solution;
3. Design and development;
4. Demonstration;
5. Evaluation;
6. Communication.

This model foresees entry points in each of the first four stages. In this research, the first entry point was identified, focusing on the problem: Verification of the efficiency of using serious games in learning in professional training, through e-learning.

The activities developed in each stage of the investigation are listed in the following subsections, following this methodology. Also, the future activities, planned to be developed in the demonstration and evaluation stages, are listed.

3.1. Identify the problem and motivate

In the first stage of the DSR, initial exploratory research was done and then a systematic literature review was conducted.

From the results of the systematic literature review [28] it was possible to confirm the problem initially identified.

The motivation was to improve the teaching-learning process in professional training with the use of serious games efficiently.

3.2. Define the objectives of a solution

After the systematic literature review, it was possible to confirm the initial research objective, that is, to develop a framework for adapting the elements of a serious game, in the context of professional training, so that both the user experience and the learning outcomes are improved.

Also, it was possible to define the framework's purposes.

3.3. Design and development

In this stage, four activities were developed:

1. Development of an initial framework based on the literature review;
2. Data collection in focus groups;
3. Data collection in interviews with experts;
4. Development of a revised framework based on the triangulation of these three methodologies.

3.4. Demonstration

In the demonstration stage of DSR, the development of a serious game and the evaluation of this artefact using the developed framework are planned.

3.5. Evaluation

In this step, we intend to evaluate the learning outcomes and some engagement indicators, resulting from the application of the serious game, developed in the previous step, to some professionals.

It is expected to be possible to identify the influences of the adaptation of the serious game on the game results and relate these to the dimensions of the framework.

After evaluating the framework, we plan to act iteratively for its improvement, i.e. to modify the framework from the evaluation results by refining the sets of dimensions and investigating the relationship between them and their application options.

3.6. Communication

Regarding the communication stage, some activities have been developed to publicize the activities of this research, such as the presentation of papers at conferences and the submission of papers to journals.

4. Activities

Following the activities carried out and their results are presented.

4.1. Systematic literature review

After the problem identification, that is the verification of the efficiency of using serious games, as a learning initiative, in professional training, restricted to e-learning, initial exploratory research and then a systematic literature review were conducted, according to the protocol provided by [20], on adaptive serious games applied to professional training.

Among the publications analyzed in this literature review, there were 7 literature reviews, in distinct areas, complementary and relevant to the review in question: Effectiveness of instructional games [16]; Practices used in serious games research [39]; Engagement in games for entertainment [4]; Empirical studies on gamification [15]; Evaluation of serious games [6]; Empirical evidence of the impacts and outcomes of computer games and serious games [5]; Serious games and gamification in professional training [21].

The systematic literature review's main results concerning the research questions are listed in Table 1.

In this literature review, it was also possible to identify the dearth of frameworks relating learning outcomes to professional competencies.

Also, as a result of the literature review, the serious game frameworks were analyzed following what [32] stated as the operations to classify and describe qualitative data.

This analysis was composed of 5 steps: Categorization, abstraction, comparison, dimensionalization and integration.

From this analysis, it was possible to identify trends and focuses of the existing frameworks, as well as their highlights according to the type of framework, whether aimed at development or evaluation, and its objective.

It was also observed the inexistence of explicit dimensions for the adaptation and for learning outcomes.

Table 1. Systematic literature review main results.

Review Question	Answers found
1. What is the influence of the game elements?	• Some game elements are quite well known (such as time constraints or reward structures, points, medals or leaderboard) and their influences are described in some works, most prominently [18]; • There is empirical evidence of the added value of some game elements, [25], such as the use of text or narration; • An influence of games, not just of a particular game element, but of games as a whole, is engagement, as highlighted by [38], where games are related to deep engagement: Passion and incorporation.
2. How should the game elements be adapted?	• Potentially, all game elements can be adapted [22]; • Some psychological models are used to adapt serious games, the main ones being Flow (optimal experience, with the loss of the notion of time, for example), FBM - Fogg Behavior Model (to motivate participation in the game, i.e., as an initial strategy for the player to reach the flow state) and SDT - Self-Determination Theory (which relates intrinsic motivation to the satisfaction of needs such as competence, autonomy and familiarity). • Better learning outcomes were identified for an adaptive serious game compared to the non-adaptive game, but there was no difference in engagement [35].
3. How to classify and organize the game elements to adapt and meet previously established goals?	• Only [23] framework predicts serious game adaptation. In this framework, instructors generate scenarios based on mission objectives and player performance.

4.2. Framework purposes

After the systematic literature review [28], the originally proposed objective of the investigation was confirmed and the framework purposes were defined:

- Include learning outcomes as dimensions of the framework;
- Group the dimensions into learning and game;

- Consider the forms of adaptation in these two groups of dimensions;
- Be used for both development and evaluation of adaptive serious games;
- Be used to improve serious games by comparing the framework‘s application at the development stage (development team) and the evaluation stage (players).

4.3. Design and development activities

Continuing the research, in the design and development phase, an initial framework was proposed, based on the systematic literature review.

Then, data were also collected in focus groups and expert interviews, so that the triangulation of these data collection methods [7] could be done next, and thus perform the first evaluation of the framework, formative and artificial, according to the FEDS framework [36].

4.3.1. Initial proposed framework

An initial proposal for the framework was developed, based on the data collected in the systematic literature review.

The main aim of this framework is to enable the convergence of learning outcomes and participant engagement with expected outcomes using the adaptation of the serious game.

Tables 2 and 3 show the dimensions of the framework and their respective aspects.

Table 2. Learning dimensions.

Dimension	Aspects
Content / Context / Framing	• Content clarity • Adequate context • Content level • Content coverage
Instructional elements	• Learning objectives approach • Evaluation types • Cognitive load and memory usage
Learning outcomes	• Objectives' compliance • Challenges' alignment • Level progression • Opportunities to redo tasks
Learning adaptation	• Learning curve • Feedback • Evolution/goals • Content change

Table 3. Game dimensions.

Dimension	Aspects
Game mechanics	• Interaction types • Game elements • Reward structures • Tasks

Game environment	• Aesthetics • Audio • Immersion • Narrative • Challenges
Results	• Points • Choices • Levels • Rewards
Game adaptation	• Adaptation decisions • Game elements change

In these tables, it is possible to identify the purposes of the framework by observing the grouping of the dimensions into learning and game and adaptation in these two groups of dimensions.

4.3.2. Focus groups

The focus groups were conducted with the participants divided into groups of "knowledgeable" and "facilitators", i.e. people who have experience in planning or developing games for professional training and people who have already used games in their work routines, such as training and development's or HR's professionals, respectively.

Activities and questions of the focus groups were grouped in four stages:

- Initial questions for participants to introduce themselves and answer general questions;
- An interactive activity where participants must associate some characteristics to certain aspects of serious games. This stage has two parts, which the first is an individual map creation and the second a group construction;
- Individual activity in which each participant answers objective questions while observing the group answers;
- Concluding questions about everything that was discussed throughout the focus group.

When comparing the results of the focus groups with the initial proposed framework for adaptive serious games in professional training, some confirmations and complementary items were observed that influenced this artefact's design.

4.3.3. Interviews with experts

The interviews were conducted with experts from Portugal and Brazil, with experience in developing and applying serious games in professional training and education, at various levels ranging from teenage education in schools to post-graduate studies.

The standardized open-ended format [33] was used in the interviews as it allows interviewees to detail as much as they wish and the researcher can use follow-up questions to elucidate each topic.

The interviews confirmed many aspects found in the literature review and also pointed out relevant topics to be considered in the game aspects of a serious game.

4.3.4. Methodology triangulation

To complement and validate the approach based on the literature review, as [8] recommends, focus groups and expert interviews were conducted to triangulate the methodologies and then develop a more consistent framework for adaptive serious games in the professional training context.

The triangulation of these three methodologies was considered the first evaluation of the framework. This evaluation had formative and artificial characteristics, according to the Framework for Evaluation in Design Science Research - FEDS [36]. It is intended to perform other evaluations of the framework during the following stages of the research, addressing the Quick & Simple strategy, described in FEDS.

This triangulation, carried out in the design and development stage, identified confirmations and complements when compared to the initially proposed framework.

The main contributions identified in this triangulation, concerning the first framework version are the confirmations in the focus groups and the interviews, and the complementary considerations about game development.

The most significant complements are related to approaches to game development and analysis, such as considerations of Ian Bogost's procedural rhetoric [2], MDA Model - Mechanics, Dynamics and Aesthetics [17], 6/11 framework [9]: 6 emotions and 11 instincts and the balance between the elements of the elemental tetrad [30].

After triangulation, the approaches to some aspects of some framework dimensions were changed, without, however, new dimensions or aspects being identified.

5. Proposed Framework

The framework presented in this paper corresponds to the revised framework after its first evaluation, the triangulation performed in the design and development stage.

Each dimension of the framework can be discretized into relevant aspects and each aspect into items to be analyzed according to the suitability of their application in the serious game.

The items that make up each aspect should reflect the existence of this aspect, its possible configurations and its influences on the serious game.

When developing a serious game, it is suggested that the technical and personal possibilities and constraints be analyzed to determine the items associated with each aspect.

For the evaluation of a serious game, the items of each aspect can be chosen according to the application context of the game.

Thus, the analysis can be performed at three levels of detail, from the most specific to the most general:

- Component items of each relevant aspect of the dimension;

- Relevant aspects of the dimension, if there are limitations to answering all the items of an aspect;
- Dimension as a whole.

According to the available resources (knowledge or time, for example), mixing the depth of analysis for each dimension is possible.

Although initially this framework suggests the items that could characterise each aspect, for each application context, theme and audience, the items related to the aspects are different.

Descriptions of the dimensions and aspects of the framework follow.

5.1. Learning dimensions

The learning dimensions are those related to the elements of serious games that concern instruction and learning. They are related to the instructional treatment given to the content, appropriate to the target audience of the game, observing characteristics such as the participant's level of knowledge and the interesting and necessary audio-visual resources to promote learning. Regarding the learning dimensions, each dimension and aspect are described below.

5.1.1. Content/Context/Framing

The content needs to be appropriate to the objectives of the serious game, providing opportunities for understanding. It must be appropriate to the target audience, concerning the professional context of the students/players and their level of knowledge and skills.

Special attention should be paid to the relevance of the topics covered and focus on the expected student outcomes. Regarding this dimension, the following aspects should be considered: Content clarity, adequate context, content level and content coverage.

5.1.2. Instructional elements

The objectives must be approached clearly, so that it is possible to evaluate if they were effectively met, respecting the limits of the students concerning their cognitive load and the use of their memory. The following aspects should be observed: Learning objectives approach, evaluation types, and cognitive load and memory usage.

5.1.3. Learning outcomes

Every serious game should have a set of expected learning outcomes. These outcomes should be aligned to the challenges and situations of the game and should be measurable throughout the game and also in pre-tests and post-tests. To develop or evaluate a serious game, it is suggested that the learning outcomes be analyzed concerning: Objectives' compliance, challenges' alignment, level progression and opportunities to redo tasks.

5.1.4. Learning adaptation

The learning dimensions can be adapted to provide better learning outcomes. According to the student's interactions, the learning curve, feedback (immediate and delayed) and the student's evolution in the game can be adapted, to improve learning outcomes. Also, the game content can be changed so each player can have better learning opportunities. Regarding the ways of adapting the learning dimensions, the relevant aspects are: Learning curve, feedback, evolution/goals and content change.

5.2. Game dimensions

The game dimensions comprise all the game mechanics and elements that a serious game may present, such as challenges, points, leaderboards, badges, game narrative, audios, and scenarios. The dimensions of this field should be considered as the ones responsible for the entertainment and engagement of the participants in serious games. Following are the dimensions, aspects and corresponding items related to game dimensions of the Framework for Adaptive Serious Games.

5.2.1. Game mechanics

The mechanics of a serious game can be characterized as its general operation, including its rules and relations among the game elements. In other words, it comprises all the audio-visual elements of the game, the way they interact with each other forming the game scenarios, besides how players interact with the game elements and with other players. Regarding game mechanics, the aspects to be analyzed are: Interaction types, game elements, reward structures and tasks.

5.2.2. Game environment

Game elements are the components used to present the game’s situations and to provide emotions to the players. A game can have several elements [31], such as scoreboards or challenges. The game elements should create a harmonious learning environment and engage players. In this sense, some aspects are considered essential: Aesthetics, audio, immersion, narrative and challenges.

5.2.3. Results

Game outcomes are measures of what happens during the game and can be used to adapt the game to, for example, keep the player in the flow state by balancing the challenges and the player's skills and knowledge. The game’s results can be, for example, the score achieved by a player, the amounts of items collected, the levels completed, and the time to overcome some challenges. These outcomes may or may not be present in the game and can be configured for various states. The most common are points, choices, levels and rewards.

5.2.4. Game adaptation

Adaptation of a game can be either offline, planned during game design and development, or online, during gameplay. It can be characterized as adaptability through player choices and parameterizations or as adaptivity through dynamic changes during gameplay. Among the forms a serious game can be adapted, the following should be highlighted: Adaptation decisions and game elements change.

6. Conclusion

From methodologies and data's triangulation, a framework for adaptive serious games was proposed with the main goal of approximating the game's learning and engagement results to the expected results, using the adaptation of the serious game. The dimensions of this framework are grouped into learning and game, corresponding to the main characteristics of a serious game. This framework provides three levels of analysis, which are dimensions, aspects and items, which can be addressed in the development and the evaluation of this type of artefact. Following the DSR methodology, the next steps in this investigation are to apply the proposed framework to develop a serious game, apply the framework to evaluate this serious game, validate this application, validate the framework by applying the developed serious game to players and analyze their game results, learning outcomes, and engagement indicators, as well as their relationship with the dimensions of the proposed framework. Beyond the paper presented at CISTI 2023 [40], the third and final version of the framework was implemented and validated in the context of the development of the Serious Game "*Encontrando Tempo*". This version operationalised the framework's principles into a working artefact used in professional training environments. The application included embedded adaptivity, flow-based content navigation, and real-time feedback mechanisms. The game was evaluated with learners, and results were analysed to assess engagement, learning effectiveness, and motivational outcomes.

These empirical validations informed final refinements to the framework, thus closing the DSR cycle and confirming the framework's applicability across development, implementation, and evaluation of adaptive Serious Games in real-world professional training scenarios.

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