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Automatic Code Generation of User-centered Serious Games: A Decade in Review

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Abstract—This paper reviews the literature on automatic code generation of user-centered serious games. We decided to break the study in two parts: one study about serious games with model driven engineering, and another study about user-centered serious games. This paper presents an extension of a paper presented at CONISOFT 20 where a systematic review of 5 years old at the time of writing was presented exclusively. The systematic literature review conducted in this paper covers a decade of information from January 2012 to June 2022. The main objective is to know the literature that helps to mitigate the costs and time of software development in serious games. The overall conclusion is that there is still work to be done to combine serious user-centered games and automatic generation. This paper is a systematic review that identifies relevant publications and provides an overview of research areas and publication venues. In addition, Research perspectives were classified according to common objectives, techniques, and approaches. Finally, is presented point out challenges and opportunities for future research and development.

Keywords: User-Centered Design, Automatic Code Generation, Serious Games, Systematic Literature Review

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1. INTRODUCTION

Serious Games (SG) can be defined as digital games with educational objectives and can be considered as an alternative and effective way to convey new knowledge to people [1]. SGs mix, with pedagogical principles, the engaging and motivational characteristics of video games (history, character design, game rules, to name a few [2]), and touch on a wide range of subjects such as science, healthcare, business practices, and history [3].

It is important to notice that a SG is a software where a student/player must do a learning task with ease of use and high levels of playability. This can be accomplished if User-Centered Design (UCD) is used. UCD is based on the needs and interests of the user so that the resulting products are useful, usable, and subsequently desirable [4]. It has been argued [4], [5], however, that most educational video games have been developed with greater emphasis on the educational aspect, losing the effectiveness, playability, and immersion that can be achieved with UCD. The study of user centeredness in SGs is then important.

The increasing complexity of systems development creates the need for tools to improve productivity in terms of time, cost, and quality [5]. One approach is automatic code generation (ACG) from models, as in model-driven engineering (MDE). MDE introduces a paradigm shift as models become the basis for software development, maintenance, and evolution [6]. By focusing on models that specify systems rather than code, a higher level of abstraction is achieved, and automation of the development process is possible. MDE and ACG have been applied in several domains.

Considering the principles of MDE presented in the study [7], which is a paradigm that encompasses the set of methods, techniques and technologies aimed at building software faster and easier, through the development and transformation of models, software development is accelerated. In research study [6] the authors direct model-driven engineering, called as Model-Driven Game Development (MDGD), towards video games. Thus, they present a structure of two essential parts. The platform independent models (PIM) define the structure and behavior of the game without addressing the characteristics of the underlying technology platform (programming language, hardware architecture, etc.). Then they continue with the platform specific model (PSM) that describes the

control mapping, which associates the actions of the game to the controller signals. These will be related to the actions of the game and the controller signals to culminate in the final source code and to be able to perform the first evaluation of a prototype.

Our general work is then interested in (semi) automatic generation of user-centric serious games. It was necessary to analyze the works previous, so we conducted a preliminary systematic literature review conducted in this paper covers a decade of information from January 2012 to June 2022.

This paper is an extension to other paper presented at CONISOFT 20 where a systematic review of 5 years old at the time of writing was presented exclusively.

In this paper presented the analysis and classification of the state of the art, a compilation is presented that contemplates the parts of model-driven engineering and integrates the UCD for the development of SG from the various proposals found in the systematic literature search. Articles about SG, ACG and UCD were previously analyzed; some of them are mentioned below.

The document is structured as follows: Section 2 background about another research. Section 3 introduces the research method that has been followed. Section 4 presents the results of the first search string. Section 5 presents the results of the second search string. Section 6 discusses our findings. Section 7 presents challenges and opportunities for future works. Finally, section 8 concludes this paper.

2. BACKGROUND

In a review of the state of the art, we discovered the concept of MDGD. In the research article [8], a systematic literature search of 26 papers in the area of MDGD is presented. One of the conclusions of the article [8] establishes that the model-driven is particularly useful for the development of video games because it provides a guide to video game developers who are not programmers.

In the paper [1], the authors presented a search for best practices for the design and evaluation of serious games. The study presented models from a pedagogical point of view, ranging from Bloom's taxonomy to constructivism, as a basis for undertaking the design of a serious game. These tips are based on the particularities they found in a list of serious games predefined by the same authors.

In research [3], the authors presented various methods for developing serious games. They presented a diversity of frameworks that are based on pedagogical theories, and others that consider a theoretical perspective for incorporating models. They exposed implementation frameworks that combine pedagogical aspects and software development concepts.

In [9] they presented a taxonomy of serious games that considered a division of areas where they have been applied, including education, training, interpersonal communication, and health care, among others. This taxonomy takes into consideration several points that are essential in the analysis of the requirements that a serious video game must have.

In [10] the authors performed an analysis of the various development engines for video games, in general, considering any type of 2D or 3D game, whether recreational or not, with no emphasis on serious games. The authors of this paper presented a list of the most popular frameworks and game engines they could find in a systematic literature search.

In research study [11], they conducted a systematic search, where they found 26 articles that performed the intervention of serious games applied to the nursing area. They were divided into four categories: procedural skills, health assessment skills, communication skills, and clinical reasoning skills. The conclusion of this research is that serious games are a tool that should be in continuous use.

The Papers [1], [3], [8], [9], [10], [11] are relevant because they exposed the issues of model-driven, user-centered design and serious games. They present advances in the state of the art, and the researchers contribute to the development of serious games from the point of view of each research.

The systematic literature review conducted in this research aimed to know, in depth, research that constitutes an advance around user-centered serious game development and the development methodologies for automatic code generation in serious games.

3. RESEARCH METHOD

The systematic review of the literature is based on the guidelines [12] and inspired by proposals such as that of [13].

Accordingly, the main objectives of this review were to answer the following questions:

- How many papers related to serious games that have used Model-driven for serious game development were proposed from January 2012 to June 2022?
- How many papers related to serious games that have used user-centered design were proposed from January 2012 to June 2022?
- What are the shortcomings of the models found for the development of serious games?

In a first effort to find a search string we tried ["Serious Games" AND "User-Centered Design" AND "Model-Driven"] in the academic google search engine, giving us poor results. Therefore, we decided to divide our systematic literature review into two parts, considering that there are many scientific articles on UCD and Model-driven. This paper presents these two parts, in which a total of 170 papers were analyzed.

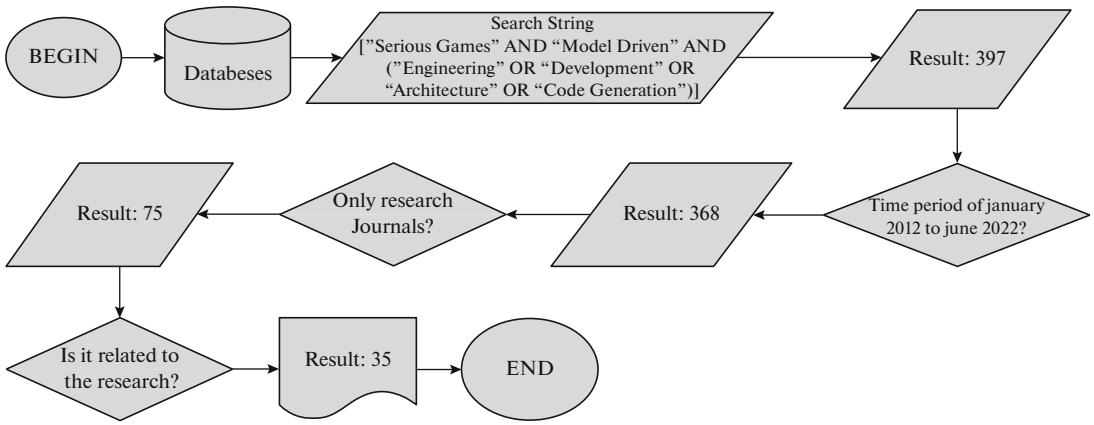

Fig. 1. Presentation of the application of the method.

As stated before, in a first effort, a single search string was considered, but given its limited results, the decision was made to consider two search strings, which would have better results and would allow us to analyze, describe and classify the results. As stated above, the literature review was divided into two different search strings. The first one [“Serious Games” AND “Model-Driven” AND (“Engineering” OR “Development” OR “Architecture” OR “Code Generation”)] was composed in this way as there may already be a wide range of definitions related to model-driven and we were concerned about discarding some of these. The second [“Serious Game” AND “User-Centered Design”] is simpler because only two areas were considered.

Inclusion and Exclusion criteria were used to select articles to be reviewed. These criteria helped us limit the search and meet the objectives of this research. If the documents did not meet the selection criteria, then they were excluded. A selection criterion was applied to narrow the search:

• Paper analyzes the articles published from January 2012 to June 2022.

• Paper published on scientific international journals.

• Papers in English.

• Paper focuses on serious games with user-centered design.

• Paper focuses on the serious games that were developed using Model-Driven.

With these selection criteria and with the search strings defined to obtain the most accurate results, the sequence of the information search is the presented below.

It was examined whether the article had specified its objective, problem, and solution. Finally, the results presented in the articles must be related to our search strings. Once the search was performed, the title, keywords and abstract of the papers were checked to ensure that they met the inclusion and exclusion criteria. They also had to be related to the search strings.

4. MODEL-DRIVEN ENGINEERING – SERIOUS GAMES

4.1. Application of the Method

Concerning the first question, as mentioned above, a detailed search in a journal database was conducted to obtain a complete bibliography, as mentioned in one of the criteria. In the first search string which is [“Serious Games” AND “Model-Driven” AND (“Engineering” OR “Development” OR “Architecture” OR “Code Generation”)], the results were as follows: a) Science Direct: 40, b) Springer Link: 292, c) Wiley Online Library: 7, d) Emerald: 8, e) ACM Digital Library: 29, f) IEEE Xplore: 13, g) SAGEPUB: 1, h) MDPI: 5, and i) Hindawi: 2 which amounts to a total of 397 papers.

The criteria of the time (January 2012 to June 2022) After excluding the results regarding the fact that they are only from journals, the total found was 75 of the 397.

To finalize the selection of the articles that we considered for this research, a quick search was carried out in titles, abstracts, and related key words, considering “Model-Driven”, and most of all, “serious games” to discard the research that was not related to serious games. Leaving us only with 35 works directly related. In the Fig. 1 presents a summary of how the application of the method was followed.

4.2. Quantitative Analysis

In this article presents 35 papers related to the search string [“Serious Games” and “Model-Driven” and (“Engineering” or “Development” or “Architecture” or “Code Generation”)] nine online databases to search the articles were used. The results were as follows: a) Science Direct: 11, b) Springer Link: 13, c)

Table 1. Papers found by magazine

No.	Journal	Quartile (Scimago)	Total
1	Multimedia Tools and Applications	Q1	4
2	Entertainment Computing	Q2	3
3	International Journal of Computer Games Technology	Q2	2
4	Procedia Computer Science	N/A	2
5	Other Journals	N/A	24

Emerald: 1, d) Wiley Online Library: 2, e) ACM Digital Library: 3, f) SAGEPUB: 1, g) MDPI: 3 and h) Hindawi: 2. Based on these results, IEEE Xplore were discarded because they did not present results.

The journal articles were published in 19 journals related to the first search string. The journal "Multimedia Tools and Applications" published most of the articles related to our search string; that is four papers. "Entertainment Computing" contributed with three papers. While "International Journal of Computer Games Technology" and "Procedia Computer Science" contributed only with two papers. The remaining 24 journals also published papers related to the search string. This illustrated in Table 1.

4.3. Qualitative Analysis

The works found were classified into 3 categories, which are explained below. Although they fall withing the criteria of the search string, we are aware that they have a different approach to the problems they want to solve.

4.3.1. Model-Driven Engineering of Serious Games. Serious or playful games need a well-defined framework to develop them. That is why the alternative to implement the phases of conceptualization, application, and monitoring in the generated applications was taken. This helped them to focus only on what is crucial for the success of the learning strategies. In the classification phase, the guide of the model-driven engineering was made use. Among these, those using the Model-Driven Engineering were presented because specifically, the tool in these documents provides a detailed description of the proposed component-based model and it also presents a validation of the requirements obtained through the use of game activity, [14–19].

Likewise, some papers define themselves as using the Model-Driven Architecture since they argue that most educational games are not supported by specific architectures because the existing ones do not include fundamental aspects such as collaboration, adaptation, or playability, or their conceptual language is difficult to understand for the educational team. To fill this gap, the architectures for designing, executing, monitoring, and adapting the learning processes supported by video games are described, considering the design and customization aspects, [20–30].

Among the works reviewed, some considered following a Model-Driven Development, where the novelty is based on the complexity of the design of the games, seeking to facilitate the design of the final user. This model does not impose the cognitive overload of learning a new design language to describe game designs that can be exported to XML files, and a game engine capable of interpreting those files and automatically generating a serious game, [31], [32].

Finally, in [33], [34] the authors used the Model-Driven Framework since it allows geolocation-based games to be edited and deployed in many places quickly. The core models and represents the structure of the game and its multimedia content (e.g., video, 3D objects), while [35], [36] present a Model-Driven Game, which serves to adapt the game design to the players' personality type. This improved the effectiveness of the games. The intention is to change the behavior and self-efficacy by changing the context concerning the player. Besides, it shows that the benefits of customizing the game improve the player's experience.

For most of the documents classified in this option, the use of a graphical modeling editor for the definition of the game domain and automatic code generation provides educational and computer strategy experts with a novel solution, which positively influences the design of this type of application.

4.3.2. Application Domains. For this classification works that have developed a serious game that was guided in the model-driven engineering are presented. In this classification, only the serious game with its characteristics is presented but details of the development are not described.

Educational: in [37] introduced the importance of making this type of software as an educational alternative for students, since some applications present it as a support for distance education that can raise the quality of education and student satisfaction. In the case of some, they present a tool that allows monitoring students and tracks their improvement while using the video game. [38], [39], [40].

Rehabilitation in [41], [42] the system that has been developed with the main objective of improving the physical and cognitive skills of students with special needs is presented. The different activities are configurable, and the tutor can modify the settings according to the needs of the student. The activities are game oriented to attract the students' attention and motivate them to learn. It is highly interactive and encourages students to be active learners. The results showed that students will be able to use the computer while improving their digital competence and their cognitive and physical skills.

4.3.3. Evaluate Gameplay. The objective of this category is to involve the final user in the discussion of the use of the serious game. For this, the category investigations, such as [43] and [44], use diverse tools that can inform us of the observations of the user. For their evaluation, these two studies were introduced in the digital games, as they played with the application. Whatever their presentation in mobile, console or pc, they discussed the motivations that the game offers them and the obstacles for the current game. They considered, as well as the cognitive stimulation, the emotional distraction and the physiotherapy for some cases, in particular, of serious games.

The increasing familiarity and age ranges play an important role in this type of classification. In most of the works it is concluded that the creation of a safe, comfortable and accessible space for learning must be considered for serious games, as a valuable tool for learning [45], [46], [47], [39].

Table 2 presents, respectively, the group of articles classified. Most of the research presented a model-driven engineering that helps serious game developers with tools that reduce development times and abstraction of concepts for serious games. Considering that a video game developer does not know the concepts that a serious game must have incorporated so that the users have an experience with playability.

Table 2. Classification of Works

No.	Journal	Quartile (Scimago)	Total
1	Entertainment Computing	Q2	11
2	British Journal of Educational Technology	Q1	7
3	Journal of Ambient Intelligence and Humanized Computing	Q1	7
4	Other Journals	N/A	72

5. USER-CENTERED DESIGN – SERIOUS GAMES

5.1. Application of the Method

Concerning the second question, as mentioned above, a detailed search to obtain a complete bibliography was conducted. In the first search string, which is ["serious games" AND "User-Centered Design"], the results were as follows: a) Science Direct: 102, b) Springer Link: 79, c) Wiley Online Library: 31, d) Emerald: 22, e) ACM Digital Library: 329, f) IEEE Xplore: 41, g) SAGEPUB: 9, h) MDPI: 2 and i) Hindawi: 1. In total 616 articles were found.

The criterion of the time (January 2012 to June 2022) After eliminating those articles that were not published in journals, the total was reduced to 214 out of the 569.

To finalize the selection of the articles that were considered for this research, a quick search was conducted in titles, abstracts, and related words considering "User-Centered Design" and mainly "Serious Games", with the aim of discarding research that was not related to serious games. Leaving us only with 135 pieces of directly related to the topic. In Fig. 2 it is possible to identify a summary of how the application of the method was followed.

5.2. Quantitative Analysis

In this article presents 135 papers related to the search string ["Serious Game" and "User-Centered Design"]. nine online databases to search the articles were used. The results were as follows: a) Science Direct: 50, b) Springer Link: 55, c) Wiley Online Library: 15, d) Emerald: 4, e) ACM Digital Library: 12, f) IEEE: 4, g) SAGEPUB: 1, h) MDPI: 2 and i) Hindawi: 1.

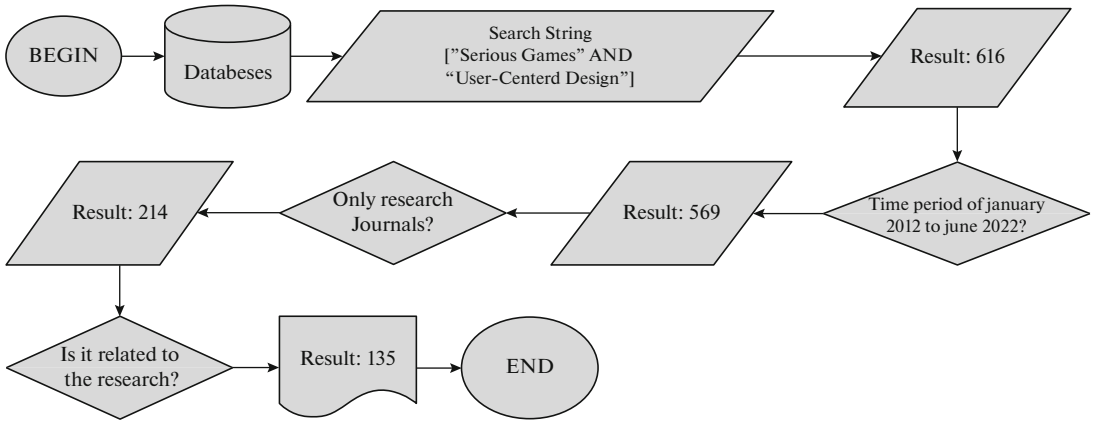

Fig. 2. Presentation of the application of the method.

Table 3. Papers found by magazine

Classification	Papers
Model-Driven Engineering of Serious Games	[14–36]
Application Domains	[37–42]
Evaluate Gameplay	[39][43–47]

Based on these results, Science Direct accounts for 41% of the total. In second place, Springer Link accounts for 31%. In third place, Wiley Online accounts for 11%, in fourth place, ACM digital accounts for 8.9%, while in fifth place Emerald accounts for 3%, in sixth place IEEE Xplore accounts for 2.2%, in seventh place MDPI accounts for 1.5%, with a contribution of 0.7% are SAGEPUB and Hindawi.

The journal articles are divided into 78 journals that published articles related to the second search string. The journal "Entertainment Computing" published most of the articles related to our search string, with eleven papers. "British Journal of Educational Technology", "Journal of Ambient Intelligence and Humanized Computing", "Procedia Computer Science" comprises seven papers, "International Journal of Human-Computer Studies" comprises six papers each one while "Multimedia Tools and Applications" supplied four papers. There were 72 other journals that also published papers related to the search string. This is illustrated in represented in the Table 3.

5.3. Qualitative Analysis

In the search 135 papers have a direct relationship with the topic. The works found were classified into four categories, which are explained below. Even though the criteria for the search string was observed, it can be ascertained that they have a different approach to the problems they want to solve.

5.3.1. Application Model or Framework. The papers in this classification presented a guide for the development of projects in the area of serious games. In these investigations, the authors give their views on how a serious game should be developed. They describe the process of generating the project from the point of view of software engineering.

For the model, they make a graphic presentation of what they consider should compose the application, but they are not specific in the points. They leave the generation of the analysis of requirements and the development of the project, as well as the evaluation, it to the criterion of the developer. The papers that work it this way are [27], [48–57].

Those that present a framework provide a more specific guide of how it should be implemented, giving details of what the best practices are in order to determine whether the application will have the success that the developer seeks. In [58–76]. The author explained the framework.

In many of the projects, the authors give us a conclusion with an application that they had developed and had already evaluated. The papers explain how they implemented a specific model for a user, so that it had a user-centered design, to solve a need or simply to improve the application.

5.3.2. User Model. For the user model classification, these are investigations that consider that users have a particularity that does not allow them to use a serious game as engineers would design it for the public to which it is addressed.

It is interesting to talk about the users because most of them for whom the user models were generated are people who have a disease or people who want to know if they can be diagnosed with this disease, as such in [16], [41], [77–81]. Likewise, there is a project [82] where the user model is oriented to a general aspect; for example, they take a single user "child" between "5-7" and with "kindergarten schooling", for the model of these users. Although the model is focused on the user, it does not provide specific details of the user. But this classification helps the developers to know the particularities and pay attention if they plan to generate an application where their target audience is children with these characteristics.

Similarly, we found these papers [83–137] that present an application that undergoes an evaluation with the target audience. They present a list of adjustments to achieve better usability. After this, they provide details of the model of the user and develop changes in the application to reevaluate and contrast the new changes with the list of requests, ending up with the requirements of the user, as the final part of the project.

5.3.3. Application Domains. In this classification are the papers that aim to use the tool to achieve an objective in a specific area.

Learning: They are all those that have the objective of being before a specific user so that the person who uses it obtains information that can later be considered acquired knowledge. This is true of [78–148] where that is the principal.

In some cases, they implemented an improvement of the serious game, and they re-submitted it to evaluation, to know if everything they considered adding was enough or if they had omitted some requirements again. As an example of this, we found [126–130].

For other cases, they evaluated some applications that lacked the consideration of user-centered design and advised that the list of requirements include improvements to the applications. These would improve the projects developed so that the user would not feel frustrated and would stop using the serious game as a tool for his benefit [149–156].

Table 4. Classification of Works

CLASSIFICATION	PAPERS	
Application Model or Framework	[27][48–76] [165] [166]	
User Model	[16] [41][77–137]	
Application Domains	Learning	[78] [79][84–87] [89] [94] [96] [98] [102] [104] [105] [109] [112] [113] [115] [116] [119] [121] [123] [124] [133] [134] [138] [139][140–148]
	Rehabilitation	[136] [157] [158] [159]
	Diagnostic	[160–164]
	Selecting	[90] [95] [107] [114] [117] [118] [120] [122] [124]
	UCD	[74] [76][167–172]
Evaluation of UCD	[11][126–130] [149–156][173–176]	

Rehabilitation: Works such as [136], [157–159] include projects that can be augmented with hardware to help people with a physical condition or that present a totally specific interaction for a user with a mental illness.

Diagnostic: Here all the applications such as [160–164] had the purpose of finding signs in the user. Whoever uses them presents particularities that can help him to know that he is a person who is suffering a condition or is prone to suffer it in a short period time.

Selecting: These applications or tools are useful to know if the user, who uses the application, has characteristics that the person who implements the tool is looking for. This is a way to evaluate the knowledge of a person in a particular case, e.g., for a job or a subject [90], [95], [107], [114], [117], [118], [120], [122], [124].

User-centered design: This tool gives us particularities of user-centered design. It teaches us to know if our project has user-centered design, as well as it shows us how it should be implemented [167–170], [74], [171], [172], [76].

Similarly, we can realize that some considerable overlapping still exists in the classification, as in some tools, before designing them, they modeled a user and advanced and used a model for the development of the application.

5.3.4. Evaluation of User-Centered Design. Several works decided to evaluate an application to know its user-centered design. For this, they conducted interviews with the public the application was directed to in order to know their point of view and how they considered their interaction, usability, and user experience. When they realized that they did not consider several things that the user required and that they had suggested to improve the usability, the application was modified.

Table 4 presents the group of papers classified according to the categories previously introduce. Some research works remain in one classification, but others have approaches that make them belong to another classification. Thus, we considered including some research studies in one or more classifications.

6. DISCUSSION

The combination of sound, art, control systems and artificial intelligence (AI) for a video game makes it totally different from traditional software development. However, software engineering techniques help game development achieve less effort and cost, and better design. The purpose of this study was to assess the state of research on software engineering processes for serious game development using an automatic code generation strategy, such as model-driven engineering. They have been submitted to user-centered design scrutiny, as well as highlighting areas that need further consideration by researchers.

In the first search string, several model-driven that are used for the development of applications were presented, but even though they can be a development tool that helps at the time of the creation of video games, they are still not so popular, and everyone chooses to start a serious game development from scratch, learning the programming language and designing the whole application. Game engines present a great development tool; however, the most sophisticated ones still require a knowledge of programming that can represent a challenge for a conventional user. It is considered that the tools that use model-driven and try to be useful do not have user-centered design patterns, making their use complicated.

When we found results of serious user-centered games, we realized that all the works were focused on a particular user, for a particular case; that is, they presented a specific application for a user that has certain particularities. The detail of this type of research is that this user model is not replicated in new applications or a new population; thus, the research has a definitive closure. Similarly, no new development models presented by the software engineers that specifically considers the analysis of the user, since they only make a

more meticulous requirement survey for the end-user, but never incorporate it as a new proposal for the development of serious games.

In the aspect of the evaluation in serious games, some have a user-centered design, but they do not work with the playability, which is a fundamental part of the games. They keep the concept of usability and miss the principal objective, which is entertainment.

However, the limited number of papers about the automatic code generation oriented to serious games gives us a very broad panorama of the lack of work that exists in that area. Before filtering our results, were found that there were several proposals, but they had not been published in journals of scientific impact. It concluded that there is an area to be explored in both areas; that is, the automatic code generation in serious games and user-centered design in serious games. The application of serious games is relevant for either, people who are engaged in education but need tools that streamline the development of these applications, or people who can develop them.

Serious games are an alternative for educators. Research suggests that they provide knowledge to their end users, but tools are needed to facilitate their development. Therefore, it considered necessary to explore new agile development tools that follow a model of automatic generation of serious games, but also consider the minimum requirements for the serious games that have a design focused on the user. In the analysis of user-centered serious games, these games remain specific to a particular user and context, which limits their contribution to new serious games that do not have those same features.

7. RECOMMENDATIONS FOR FUTURE RESEARCH

Interesting areas of opportunity were discussed regarding agile SG development looking for a solution to the challenges for developing SGs: 1) developing better SGs, with 2) less budget and resources, and 3) with time [177]. This is where MDE and ACG can propose a solution, along with UCD.

Therefore, we present below the challenges, opportunities for research and the development of future work. Proposing to follow the bases of the MDE and the UCD. The deficiencies and research areas where models need to be developed and a successful ACG that meets most of the requirements requested by the user needs to be developed.

Model-Driven Game Development (MDGD) [8] presents a structure of two essential parts. The platform independent models (PIM), the platform specific model (PSM), moving to the final part in the generation of the final source code, to perform the first evaluation of a prototype.

Consider as an example the structure proposed by [181], [182] using UML to present the Model-driven. Presenting a structure that can be interpreted by the developer.

Model for functional and non-functional requirements of serious games

Studies such as [16], [41], [77–137] present user models to solve end-user problems with positive conclusions from them. However, the problem with these studies presenting a user model is that they lack a guide to streamline the creation process from a requirements analysis. Functional and non-functional requirements that help us to describe the behavior of the SG for its functionality, and focus the change on the design or implementation, the functional requirements give priority to Learning Analytics, motivation, and types of games, while in the non-functional may be the Interoperability of learning tools, connectivity and scalability. To mention a few, work should be done to propose a guide that presents a greater diversity and that are related to the SG.

Task Model for Serious Games

The user task model helps to understand the activities performed by the user in the SG. This type of modeling is separated into four types of existing tasks: user tasks, application tasks, interaction tasks and abstract tasks. This model can be represented in a Concur Task Tree (CTT). But this model has not been integrated into the model proposals for SG development, which would provide developers with time-saving work.

User or player model for serious games

In the articles [14–36] the researchers presented proposals in which they used the MD for the development of serious games, the results and conclusions were positive.

The problem that exists is that no proposal considers the integration of the UCD. The user model should describe the particularities of the target user, with an abstract representation of the information that we can know about the end user.

This is to provide the adaptability in appearance and preferences that the user needs. Some proposals such as that of [50] using the TURF (Task, Users, Representation, and Function) approach or that of the authors [99] using the ISO 9241-210:2010 standard for user-centered design. It is necessary to know the players as there is research such as that of the authors of [82] who considered a particular modeling by their older adult users.

The player model is also considered where the role that the player has, the tasks to be performed and how to achieve them, the goals and the different states in which these goals of the SG are found. Therefore, we work on a user model that incorporates several tech-

niques to know the characteristics of the final player and provide a UCD.

Model for game mechanics

The game mechanics would determine the rules of the video game, the definition of the rewards, the storytelling that authors [62] & [96] consider the most important part of a video game, the feedback, the debriefing, the objectives and mechanics of the game where the mobile and static actors (Player and enemies), the environment and design (scenarios), definition of the scoring rules, and hardware definitions are presented. In several works it is taken for granted that developers know the elements that a SG must have.

Model of pedagogical/playful objectives

It is necessary to work on what the teacher wishes to present in the SG and how it can be presented, since this aspect is not considered in the MDGD proposal. The teacher must determine the competencies to achieved by the player. An example to define the model could be the 4 steps proposed in the research of [49] step 1 identification and description of the activity, step 2 representation of the game sequence, step 3 identification of the actions, tools and objectives of the game, description of the objective to be fulfilled with the exercise, to relate the mechanics of the game with the learning objective.

Model for scenarios and assets

A SG needs a model to define the levels and from these the scenes with a brief description, the characteristics of the playable or non-playable objects of the scene and the identification of the educational challenges. For the scenes to present their graphic part, with the graphic design sketches.

Stringent evaluations

The Evaluations they use in their research mention the success of serious games with end users with product acceptance and functionality, but do not subject the end result of the serious game to strict evaluation by experts who might conclude that the serious game has playability. Some others conduct ad-hoc interviews with users to get their opinion. Consider in evaluating the presentation of your developed product on various electronic devices (mobile, tablet, pc or game console) to determine which device is the most suitable for your SG. Therefore, it is necessary to work on an evaluation of the final product that can provided in the MDGD. Therefore, it should not be left to drift to maintain the balance in the middle point of learning and entertainment so that a serious game can be had that provides the necessary elements for the student to continue using it and the teacher to see reflected the reinforcement of knowledge that he wants his students to obtain.

The following are the final conclusions of the work presented in this academic article.

8. CONCLUSIONS

The research works reported above focus on streamlining the development of serious games, but they ignore an important part: the user-centered design, being the design the first thing that the user visualizes and should be more important. Because of this, even if the serious game meets all the functions and pedagogical requirements requested by the user, if the interaction does not have an appropriate design (user-centered), it becomes a poorly rated aspect by the end user. UCD is an approach to the design and development of interactive systems that seeks to make them more usable. UCD helps to determine whether the application is useful, usable and, subsequently, desirable [4]. However, in research study [180], they change the concept of usability to playability, which they define as the set of properties that describe the player's experience with a given game system whose main objective is to amuse and entertain in a satisfactory way It proposes a series of attributes, which are very similar to the aspects of usability.

The research compiles some of the information found shows the integration of various multidisciplinary points. Section 7 helps to clearly identify the user requirements and needs of user-centered design with the work found in the systematic review, as well as the integration of model-driven orientation, which provides a software engineering foundation that can serve as a guide.

The compilation provides rules and guidelines on how serious games could be adapted to the user and serve as support material for the teacher. As future work, we wish to propose a model, methodology considering indicators such as efficiency and learning experience. At the same time, we want to apply more case studies to support the validation of the methodology. We are working on user-centered educational applications to validate if the proposed methodology contributes to streamline the process to obtain applications that meet the criteria of usability and playability.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

1. Catalano, C.E., Luccini, A.M., and Mortara, M., Guidelines for an effective design of serious games, *Int. J. Serious Games,* 2014, vol. 1, no. 1. https://doi.org/10.17083/ijsg.v1i1.8
2. Frasca, G., Juego, videojuego y creación de sentido, *Una introducción,* 2009, vol. 1, pp. 37–44. https://doi.org/10.29378/plurais.2447-9373.2010.v1.n2.%p
3. Hanes, L. and Stone, R., A model of heritage content to support the design and analysis of video games for history education, *J. Comput. Educ.,* 2019, vol. 6, no. 4, pp. 587–612. https://doi.org/10.1007/s40692-018-0120-2
4. Nielsen, J., *Usability 101: Introduction to Usability,* Nielsen Norman Group, 2012. https://www.nngroup.com/articles/usability-101-introduction-to-usability. Accessed Apr. 07, 2022.
5. Blow, J., Game development: harder than you think, *Queue,* 2004, vol. 1, no. 10, pp. 28–37. https://doi.org/10.1145/971564.971590
6. Reyno, E.M. and Carsí Cubel, J., Automatic prototyping in model-driven game development, *Comput. Entertain.,* 2009, vol. 7, no. 2, pp. 1–9. https://doi.org/10.1145/1541895.1541909
7. Ruiz-Rube, I., Dodero, J.M., and Ruiz, M., Ingeniería Dirigida por Modelos como soporte a la gestion de procesos software, *II Jornadas Predoctorales,* la Univ. Cádiz: Escuela Superior de Ingeniería, 2010.
8. Zhu, M. and Wang, A.I., Model-driven game development: a literature review, *ACM Comput. Surv.,* 2019, vol. 52, no. 6. https://doi.org/10.1145/3365000
9. Laamarti, F., Eid, M., and El Saddik, A., An overview of serious games, *Int. J. Comput. Games Technol.,* 2014, vol. 2014, no. 3. https://doi.org/10.1155/2014/358152
10. Cowan, B. and Kapralos, B., A survey of frameworks and game engines for serious game development, *Proc. IEEE 14th Int. Conf. on Advanced Learning Technologies,* Athenes, 2014, pp. 662–664. https://doi.org/10.1109/ICALT.2014.194
11. Tan, A.J.Q., Lau, C.C.S., and Liaw, S.Y., Serious games in nursing education: an integrative review, *Proc. 9th Int. Conf. on Virtual Worlds and Games for Serious Applications, VS-Games 2017,* Athenes, 2017, pp. 187–188. https://doi.org/10.1109/VS-GAMES.2017.8056599
12. Kitchenham, B., Pearl Brereton, O., Budgen, D., Turner, M., Bailey, J., and Linkman, S., Systematic literature reviews in software engineering – a systematic literature review, *Inf. Software Technol.,* 2009, vol. 51, no. 1, pp. 7–15. https://doi.org/10.1016/j.infsof.2008.09.009
13. Hong, J., Suh, E., and Kim, S.J., Context-aware systems: a literature review and classification, *Expert Syst. Appl.,* 2009, vol. 36, no. 4, pp. 8509–8522. file:///C:/Documentos/Investigacion/Proyecto CB CONACYT/Soporte/Docs/context-aware literature review.pdf.
14. Calderón, A., Boubeta-Puig, J., and Ruiz, M., MEdit4CEP-Gam: a model-driven approach for user-friendly gamification design, monitoring and code generation in CEP-based systems, *Inf. Software Technol.,* 2018, vol. 95, pp. 238–264. https://doi.org/10.1016/j.infsof.2017.11.009
15. Pérez-Berenguer, D. and García-Molina, J., A standard-based architecture to support learning interoperability: a practical experience in gamification, *Software – Pract. Exp.,* 2018, vol. 48, no. 6, pp. 1238–1268. https://doi.org/10.1002/spe.2572
16. Teipel, S., et al., Use of nonintrusive sensor-based information and communication technology for real-world evidence for clinical trials in dementia, *Alzheimer's Dement.,* 2018, vol. 14, no. 9, pp. 1216–1231. https://doi.org/10.1016/j.jalz.2018.05.003
17. De Lope, R.P., Medina-Medina, N., Urbieta, M., Lliteras, A.B., and Mora García, A., A novel UML-based methodology for modeling adventure-based educational games, *Entertain. Comput.,* 2021, vol. 38, no. 2, p. 100429. https://doi.org/10.1016/j.entcom.2021.100429
18. Antunes, A. and Madeira, R.N., PLAY – model-based platform to support therapeutic serious games design, *Procedia Comput. Sci.,* 2021, vol. 198, no. 2018, pp. 211–218. https://doi.org/10.1016/j.procs.2021.12.230
19. Pérez, F., Lapeña, R., Marcén, A.C., and Cetina, C., Topic modeling for feature location in software models: studying both code generation and interpreted models, *Inf. Software Technol.,* 2021, vol. 140, p. 106676. https://doi.org/10.1016/j.infsof.2021.106676
20. Martínez-Pernía, D., et al., Using game authoring platforms to develop screen-based simulated functional assessments in persons with executive dysfunction following traumatic brain injury, *J. Biomed. Inform.,* 2017, vol. 74, pp. 71–84. https://doi.org/10.1016/j.jbi.2017.08.012
21. Oberdörfer, S. and Latoschik, M.E., Predicting learning effects of computer games using the Gamified Knowledge Encoding Model, *Entertain. Comput.,* 2019, vol. 32, p. 100315. https://doi.org/10.1016/j.entcom.2019.100315
22. Padilla-Zea, N., Medina, N.M., Gutiérrez Vela, F.L., Paderewski, P., and Collazos, C.A., PLAGER-VG: platform for managing educational multiplayer video games, *Multimed. Tools Appl.,* 2018, vol. 77, no. 2, pp. 2115–2152. https://doi.org/10.1007/s11042-017-4376-8
23. Thomas, A., Menassa, C.C., and Kamat, V.R., Lightweight and adaptive building simulation (LABS) framework for integrated building energy and thermal comfort analysis, *Build. Simul.,* 2017, vol. 10, no. 6, pp. 1023–1044. https://doi.org/10.1007/s12273-017-0409-5

24. Reinkensmeyer, D.J., et al., Computational neurorehabilitation: modeling plasticity and learning to predict recovery, *J. Neuroeng. Rehabil.,* 2016, vol. 13, no. 1, pp. 1–25. https://doi.org/10.1186/s12984-016-0148-3

25. Torrens, P.M., Intertwining agents and environments, *Environ. Earth Sci.,* 2015, vol. 74, no. 10, pp. 7117–7131. https://doi.org/10.1007/s12665-015-4738-3

26. Muñoz, J.E., Gouveia, E.R., Cameirão, M.S., and Badia, S.B.I., Physiolab – a multivariate physiological computing toolbox for ECG, EMG and EDA signals: a case of study of cardiorespiratory fitness assessment in the elderly population, *Multimed. Tools Appl.,* 2018, vol. 77, no. 9, pp. 11511–11546. https://doi.org/10.1007/s11042-017-5069-z

27. Kritikos, K., Plexousakis, D., and Paternò, F., Task model-driven realization of interactive application functionality through services, *ACM Trans. Interact. Intell. Syst.,* 2014, vol. 3, no. 4. https://doi.org/10.1145/2559979

28. Feron, H., Lehmann, A., and Josse, F., A generic architecture and validation considerations for tactical combat casualty care serious games, *J. Def. Model. Simul.,* 2015, vol. 12, no. 3, pp. 319–334. https://doi.org/10.1177/1548512914546148

29. Fanini, B., Pagano, A., and Ferdani, D., A novel immersive VR game model for recontextualization in virtual environments: the μ VRmodel, *Multimodal Technol. Interact.,* 2018, vol. 2, no. 2. https://doi.org/10.3390/mti2020020

30. Mestadi, W., Nafil, K., Touahni, R., and Messoussi, R., An assessment of serious games technology: toward an architecture for serious games design, *Int. J. Comput. Games Technol.,* 2018, vol. 2018, p. 9834565. https://doi.org/10.1155/2018/9834565

31. Zarraonandia, T., Diaz, P., and Aedo, I., Using combinatorial creativity to support end-user design of digital games, *Multimed. Tools Appl.,* 2017, vol. 76, no. 6, pp. 9073–9098. https://doi.org/10.1007/s11042-016-3457-4

32. Bozzon, A., Fraternali, P., Galli, L., and Karam, R., Modeling crowd sourcing scenarios in socially-enabled human computation applications, *J. Data Semant.,* 2014, vol. 3, no. 3, pp. 169–188. https://doi.org/10.1007/s13740-013-0032-2

33. Ferreira, C., Maia, L.F., de Salles, C., Trinta, F., and Viana, W., Modelling and transposition of location-based games, *Entertain. Comput.,* 2019, vol. 30, p. 100295. https://doi.org/10.1016/j.entcom.2019.100295

34. van Rozen, R., Languages of games and play: a systematic mMapping study, *ACM Comput. Surv.,* 2021, vol. 53, no. 6, pp. 1–37. https://doi.org/10.1145/3412843

35. Orji, R., Mandryk, R.L., and Vassileva, J., Improving the efficacy of games for change using personalization models, *ACM Trans. Comput. Interact.,* 2017, vol. 24, no. 5. https://doi.org/10.1145/3119929

36. Aleem, S., Capretz, L.F., and Ahmed, F., Critical success factors to improve the game development process from a developer's perspective, *J. Comput. Sci. Technol.,* 2016, vol. **31**, no. 5, pp. 925–950. https://doi.org/10.1007/s11390-016-1673-z

37. Minović, M., Milovanović, M., Šošević, U., and Conde González, M.Á., Visualisation of student learning model in serious games, *Comput. Human Behav.,* 2015, vol. 47, pp. 98–107. https://doi.org/10.1016/j.chb.2014.09.005

38. Rumeser, D. and Emsley, M., Design and evaluation of the project and program crashing games, *J. Appl. Res. High. Educ.,* 2022, vol. 14, no. 1, pp. 471–488. https://doi.org/10.1108/JARHE-07-2017-0083

39. Predescu, A., Arsene, D., Pahont, B., Mocanu, M., and Chiru, C., A serious gaming approach for crowdsensing in urban water infrastructure with blockchain support, *Appl. Sci.,* 2021, vol. 11, no. 4, pp. 1–32. https://doi.org/10.3390/app11041449

40. Furtado, L.S., De Souza, R.F., Lima, J.L.D.R., and Oliveira, S.R.B., Teaching method for software measurement process based on gamification or serious games: a systematic review of the literature, *Int. J. Comput. Games Technol.,* 2021, vol. 2021, p. 8873997. https://doi.org/10.1155/2021/8873997

41. Ojeda-Castelo, J.J., Piedra-Fernandez, J.A., Iribarne, L., and Bernal-Bravo, C., KiNEEt: application for learning and rehabilitation in special educational needs, *Multimed. Tools Appl.,* 2018, vol. 77, no. 18, pp. 24013–24039. https://doi.org/10.1007/s11042-018-5678-1

42. Yamin, M.M., Katt, B., and Nowostawski, M., Serious games as a tool to model attack and defense scenarios for cyber-security exercises, *Comput. Secur.,* 2021, vol. 110, p. 102450. https://doi.org/10.1016/j.cose.2021.102450

43. Tong, T., et al., Rapid deployment and evaluation of mobile serious games: a cognitive assessment case study, *Procedia Comput. Sci.,* 2015, vol. 69, pp. 96–103. https://doi.org/10.1016/j.procs.2015.10.010

44. Gibson, D.C. and Webb, M.E., Data science in educational assessment, *Educ. Inf. Technol.,* 2015, vol. 20, no. 4, pp. 697–713. https://doi.org/10.1007/s10639-015-9411-7

45. Khalili-Mahani, N., et al., For whom the games toll: a qualitative and intergenerational evaluation of what is serious in games for older adults, *Comput. Games J.,* 2020, no. 0123456789. https://doi.org/10.1007/s40869-020-00103-7

46. Rieger. C. and Majchrzak, T. A., Towards the definitive evaluation framework for cross-platform app development approaches, *J. Syst. Software,* 2019, vol. 153, pp. 175–199. https://doi.org/10.1016/j.jss.2019.04.001

47. Koch, J., Gomse, M., and Schüppstuhl, T., Digital game-based examination for sensor placement in context of an Industry 4.0 lecture using the unity 3D engine – a case study, *Procedia Manuf.,* 2021, vol. 55, no. C, pp. 563–570. https://doi.org/10.1016/j.promfg.2021.10.077

48. Coghlan, A. and Carter, L., Serious games as interpretive tools in complex natural tourist attractions, *J.*

Hosp. Tour. Manag., 2020, vol. 42, pp. 258–265. https://doi.org/10.1016/j.jhtm.2020.01.010

49. Carvalho, M.B., et al., An activity theory-based model for serious games analysis and conceptual design, *Comput. Educ.,* 2015, vol. 87, pp. 166–181. https://doi.org/10.1016/j.compedu.2015.03.023
50. Johnsen, H.M., Fossum, M., Vivekananda-Schmidt, P., Fruhling, A., and Slettebø, A., Teaching clinical reasoning and decision-making skills to nursing students: design, development, and usability evaluation of a serious game, *Int. J. Med. Inform.,* 2016, vol. 94, pp. 39–48. https://doi.org/10.1016/j.ijmedinf.2016.06.014
51. Kiili, K., Lainema, T., de Freitas, S., and Arnab, S., Flow framework for analyzing the quality of educational games, *Entertain. Comput.,* 2014, vol. **5**, no. 4, pp. 367–377. https://doi.org/10.1016/j.entcom.2014.08.002
52. Gray, S.I., Robertson, J., Manches, A., and Rajendran, G., BrainQuest: the use of motivational design theories to create a cognitive training game supporting hot executive function, *Int. J. Hum. Comput. Stud.,* 2019, vol. 127, pp. 124–149. https://doi.org/10.1016/j.ijhcs.2018.08.004
53. Marcucci, E., Gatta, V., and Le Pira, M., Gamification design to foster stakeholder engagement and behavior change: an application to urban freight transport, *Transp. Res. Part A Policy Pract.,* 2018, vol. 118, pp. 119–132. https://doi.org/10.1016/j.tra.2018.08.028
54. Xu, F., Buhalis, D., and Weber, J., Serious games and the gamification of tourism, *Tour. Manag.,* 2017, vol. 60, pp. 244–256. https://doi.org/10.1016/j.tourman.2016.11.020
55. Huang, H., Ng, K.H., Bedwell, B., and Benford, S., A card-based internet of things game ideation tool for museum context, *J. Ambient Intell. Humaniz. Comput.,* 2021, vol. 12, no. 10, pp. 9229–9240. https://doi.org/10.1007/s12652-020-02627-2
56. Vardaxoglou, G. and Baralou, E., Developing a platform for serious gaming: open innovation through closed innovation, *Procedia Comput. Sci.,* 2012, vol. 15, pp. 111–121, https://doi.org/10.1016/j.procs.2012.10.063
57. De Freitas, S. and Routledge, H., Designing leadership and soft skills in educational games: the e-leadership and soft skills educational games design model (ELESS), *Br. J. Educ. Technol.,* 2013, vol. 44, no. 6, pp. 951–968. https://doi.org/10.1111/bjet.12034
58. van Dooren, M.M.M., Siriaraya, P., Visch, V., Spijkerman, R., and Bijkerk, L., Reflections on the design, implementation, and adoption of a gamified eHealth application in youth mental healthcare, *Entertain. Comput.,* 2019, vol. 31, p. 100305. https://doi.org/10.1016/j.entcom.2019.100305
59. Seaborn, K. and Fels, D.I., Gamification in theory and action: a survey, *Int. J. Hum. Comput. Stud.,* 2015, vol. 74, pp. 14–31. https://doi.org/10.1016/j.ijhcs.2014.09.006
60. Ahmad, N.B., Barakji, S.A.R., Shahada, T.M.A., and Anabtawi, Z.A., How to launch a successful video game: a framework, *Entertain. Comput.,* 2017, vol. 23, pp. 1–11. https://doi.org/10.1016/j.entcom.2017.08.001
61. Urh, M., Vukovic, G., Jereb, E., and Pintar, R., The model for Introduction of gamification into E-learning in higher education, *Procedia – Soc. Behav. Sci.,* 2015, vol. 197, pp. 388–397. https://doi.org/10.1016/j.sbspro.2015.07.154
62. Padilla-Zea, N., Gutierrez, F.L., López-Arcos, J.R., Abad-Arranz, A., and Paderewski, P., Modeling storytelling to be used in educational video games, *Comput. Human Behav.,* 2014, vol. 31, no. 1, pp. 461–474. https://doi.org/10.1016/j.chb.2013.04.020
63. Fischinger, D., et al., Hobbit, a care robot supporting independent living at home: first prototype and lessons learned, *Rob. Auton. Syst.,* 2016, vol. 75, pp. 60–78. https://doi.org/10.1016/j.robot.2014.09.029
64. Front, A., Rieu, D., Santorum, M., and Movahedian, F., A participative end-user method for multi-perspective business process elicitation and improvement, *Software Syst. Model.,* 2017, vol. 16, no. 3, pp. 691–714. https://doi.org/10.1007/s10270-015-0489-6
65. Räisänen, T., Ypsilanti, A., Ropes, D., Vivas, A.B., Viitala, M., and Ijäs, T., Examining the requirements for an intergenerational learning game, *Educ. Inf. Technol.,* 2014, vol. 19, no. 3, pp. 531–547. https://doi.org/10.1007/s10639-014-9324-x
66. Kourouthanassis, P.E., Boletsis, C., and Lekakos, G., Demystifying the design of mobile augmented reality applications, *Multimed. Tools Appl.,* 2013, vol. 74, no. 3, pp. 1045–1066. https://doi.org/10.1007/s11042-013-1710-7
67. Shahri, A., Hosseini, M., Taylor, J., Stefanidis, A., Phalp, K., and Ali, R., *Engineering Digital Motivation in Businesses: a Modelling and Analysis Framework,* London: Springer, 2019, vol. 1.
68. Priego-Roche, L.M., Front, A., and Rieu, D., A framework for virtual organization requirements, *Requir. Eng.,* 2016, vol. 21, no. 4, pp. 439–460. https://doi.org/10.1007/s00766-015-0223-5
69. Hersh, M. and Leporini, B., Editorial: serious games, education and inclusion for disabled people, *Br. J. Educ. Technol.,* 2018, vol. 49, no. 4, pp. 587–595. https://doi.org/10.1111/bjet.12650
70. Terras, M.M. and Boyle, E.A., Integrating games as a means to develop e-learning: Insights from a psychological perspective, *Br. J. Educ. Technol.,* 2019, vol. 50, no. 3, pp. 1049–1059. https://doi.org/10.1111/bjet.12784
71. Dimeff, L.A. and Koerner, K., Fulfilling the promise of behavioral health technologies to improve public health impact and reduce public health disparities: a commentary, *Clin. Psychol. Sci. Pract.,* 2019, vol. 26, no. 1, pp. 1–4. https://doi.org/10.1111/cpsp.12276
72. Peñeñory, V.M., Collazos, C.A., Bacca, Á.F., Manresa-Yee, C., Cano, S.P., and Fadoun, H.M., APRehab: a methodology for serious games design oriented to psychomotor rehabilitation in children with hearing impairments, *Univers. Access Inf. Soc.,* 2020,

no. 0123456789.
https://doi.org/10.1007/s10209-020-00728-5

73. Ramos-Aguiar, L.R. and Alvarez-Rodriguez, F.J., Teaching emotions in children with autism spectrum disorder through a computer program with tangible interfaces, *Rev. Iberoam. Tecnol. del Aprendiz.,* 2021 vol. 16, no. 4, pp. 365–371.
https://doi.org/10.1109/RITA.2021.3125901

74. Böckle, M., Novak, J., and Bick, M., Exploring gamified persuasive system design for energy saving, *J. Enterp. Inf. Manag.,* 2020, vol. 33, no. 6, pp. 1337–1356.
https://doi.org/10.1108/JEIM-02-2019-0032

75. Wang, X., Goh, D.H.L., Lim, E.P., and Vu, A.W.L., Understanding the determinants of human computation game acceptance: the effects of aesthetic experience and output quality, *Online Inf. Rev.,* 2016, vol. 40, no. 4, pp. 481–496.
https://doi.org/10.1108/OIR-06-2015-0203

76. Carrión-Toro, M., Santorum, M., Acosta-Vargas, P., Aguilar, J., and Pérez, M., iPlus a user-centered methodology for serious games design, *Appl. Sci.,* 2020, vol. 10, no. 24, pp. 1–33.
https://doi.org/10.3390/app10249007

77. Kondylakis, H., et al., Patient empowerment for cancer patients through a novel ICT infrastructure, *J. Biomed. Inform.,* 2020, vol. 101, p. 103342.
https://doi.org/10.1016/j.jbi.2019.103342

78. Cano, S., Collazos, C.A., Flórez Aristizábal, L., Gonzalez, C.S., and Moreira, F., Towards a methodology for user experience assessment of serious games with children with cochlear implants, *Telemat. Inf.,* 2018, vol. 35, no. 4, pp. 993–1004.
https://doi.org/10.1016/j.tele.2017.09.011

79. Fanfarelli, J.R., McDaniel, R., and Crossley, C., Adapting UX to the design of healthcare games and applications, *Entertain. Comput.,* 2018, vol. 28, pp. 21–31.
https://doi.org/10.1016/j.entcom.2018.08.001

80. Fernandez-Cervantes, V., Neubauer, N., Hunter, B., Stroulia, E., and Liu, L., VirtualGym: a kinect-based system for seniors exercising at home, *Entertain. Comput.,* 2018, vol. 27, pp. 60–72.
https://doi.org/10.1016/j.entcom.2018.04.001

81. Menghi, R., Papetti, A., and Germani, M., Product service platform to improve care systems for elderly living at home, *Heal. Policy Technol.,* 2019, vol. 8, no. 4, pp. 393–401.
https://doi.org/10.1016/j.hlpt.2019.10.004

82. Havukainen, M., Laine, T.H., Martikainen, T., and Sutinen, E., A case study on co-designing digital games with older adults and children: game elements, assets, and challenges, *Comput. Games J.,* 2020, no. 0123456789.
https://doi.org/10.1007/s40869-020-00100-w

83. O'Connor, S., Shuttleworth, J., Colreavy-Donnelly, S., and Liarokapis, F., Assessing the perceived realism of agent grouping dynamics for adaptation and simulation, *Entertain. Comput.,* 2019, vol. 32, p. 100323.
https://doi.org/10.1016/j.entcom.2019.100323

84. Johnson, C.M., McIlwain, S., Gray, O., Willson, B., and Vorderstrasse, A., Creating a sustainable collaborative consumer health application for chronic disease self-management, *J. Biomed. Inform.,* 2017, vol. 71, pp. 198–206.
https://doi.org/10.1016/j.jbi.2017.06.004

85. López, S., Cervantes, J.A., Cervantes, S., Molina, J., and Cervantes, F., The plausibility of using unmanned aerial vehicles as a serious game for dealing with attention deficit-hyperactivity disorder, *Cogn. Syst. Res.,* 2020, vol. 59, pp. 160–170.
https://doi.org/10.1016/j.cogsys.2019.09.013

86. Quint, F., Sebastian, K., and Gorecky, D., A mixed-reality learning environment, *Procedia Comput. Sci.,* 2015, vol. 75, no. Vare, pp. 43–48.
https://doi.org/10.1016/j.procs.2015.12.199

87. Koivisto, J.M., Haavisto, E., Niemi, H., Haho, P., Nylund, S., and Multisilta, J., Design principles for simulation games for learning clinical reasoning: a design-based research approach, *Nurse Educ. Today,* 2018, vol. 60, pp. 114–120.
https://doi.org/10.1016/j.nedt.2017.10.002

88. Gerling, K.M., Linehan, C., Kirman, B., Kalyn, M.R., Evans, A.B., and Hicks, K.C., Creating wheelchair-controlled video games: challenges and opportunities when involving young people with mobility impairments and game design experts, *Int. J. Hum. Comput. Stud.,* 2016, vol. 94, pp. 64–73.
https://doi.org/10.1016/j.ijhcs.2015.08.009

89. Cinquin, P.A., Guitton, P., and Sauzéon, H., Online e-learning and cognitive disabilities: a systematic review, *Comput. Educ.,* 2019 vol. 130, pp. 152–167.
https://doi.org/10.1016/j.compedu.2018.12.004

90. Aebli, A., Tourists' motives for gamified technology use, *Ann. Tour. Res.,* 2019, vol. 78, p. 102753.
https://doi.org/10.1016/j.annals.2019.102753

91. Ingram, J. and Gaskell, P., Searching for meaning: co-constructing ontologies with stakeholders for smarter search engines in agriculture, *NJAS – Wageningen J. Life Sci.,* 2019, vol. 90–91, p. 100300.
https://doi.org/10.1016/j.njas.2019.04.006

92. Scott, M.J., Spyridonis, F., and Ghinea, G., Designing for designers: towards the development of accessible ICT products and services using the VERITAS framework, *Comput. Stand. Interfaces,* 2015, vol. 42, pp. 113–124.
https://doi.org/10.1016/j.csi.2015.05.004

93. Tan, J.L., Goh, D.H.L., Ang, R.P., and Huan, V.S., Learning efficacy and user acceptance of a game-based social skills learning environment, *Int. J. Child-Comput. Interact.,* 2016, vol. 9–10, pp. 1–19.
https://doi.org/10.1016/j.ijcci.2016.09.001

94. Lokshina, I.V. and Durkin, B.J., Redesigning the healthcare model to address obesity problem using the integration of processes and mobile technologies: facing a worldwide epidemic in an innovative manner, *Wirel. Pers. Commun.,* 2017, vol. 96, no. 4, pp. 5483–5498.
https://doi.org/10.1007/s11277-016-3752-4

95. Hocine, N., Gouaich, A., Cerri, S.A., Mottet, D., Froger, J., and Laffont, I., Adaptation in serious games for upper-limb rehabilitation: an approach to improve training outcomes, *User Model. User-adapt. Interact.,* 2015, vol. 25, no. 1, pp. 65–98.
https://doi.org/10.1007/s11257-015-9154-6

96. Vayanou, M., Ioannidis, Y., Loumos, G., and Kargas, A., *How to Play Storytelling Games with Masterpieces: from Art Galleries to Hybrid Board Games,* Berlin Heidelberg: Springer, 2019, vol. 6, no. 1.

97. Martinho, D., Carneiro, J., Corchado, J.M., and Marreiros, G., A systematic review of gamification techniques applied to elderly care, *Artif. Intell. Rev.,* 2020, no. 0123456789. https://doi.org/10.1007/s10462-020-09809-6

98. Palumbo, F., et al., Reliability and human factors in ambient assisted living environments: the DOREMI case study, *J. Reliab. Intell. Environ.,* 2017, vol. 3, no. 3, pp. 139–157. https://doi.org/10.1007/s40860-017-0042-1

99. Ivanov, R., Blind-environment interaction through voice augmented objects, *J. Multimodal User Interfaces,* 2014, vol. 8, no. 4, pp. 345–365. https://doi.org/10.1007/s12193-014-0166-z

100. Tuerk, P.W., Schaeffer, C.M., McGuire, J.F., Adams Larsen, M., Capobianco, N., and Piacentini, J., Adapting evidence-based treatments for digital technologies: a critical review of functions, tools, and the use of branded solutions, *Curr. Psychiatry Rep.,* 2019, vol. 21, no. 10. https://doi.org/10.1007/s11920-019-1092-2

101. Kosmas, P., et al., Enhancing accessibility in cultural heritage environments: considerations for social computing, *Univers. Access Inf. Soc.,* 2019, vol. 19, pp. 471–482. https://doi.org/10.1007/s10209-019-00651-4

102. Puigdomenech, E., et al., Promoting healthy teenage behaviour across three European countries through the use of a novel smartphone technology platform, PEGASO fit for future: study protocol of a quasi-experimental, controlled, multi-centre trial, *BMC Med. Inform. Decis. Mak.,* 2019, vol. 19, no. 1, pp. 1–13. https://doi.org/10.1186/s12911-019-0958-x

103. Nisiforou, E.A. and Zaphiris, P., Let me play: unfolding the research landscape on ICT as a play-based tool for children with disabilities, *Univers. Access Inf. Soc.,* 2020, vol. 19, no. 1, pp. 157–167. https://doi.org/10.1007/s10209-018-0627-3

104. Stuij, S.M., et al., Developing a digital communication training tool on information-provision in oncology: uncovering learning needs and training preferences, *BMC Med. Educ.,* 2018, vol. 18, no. 1, pp. 1–12. https://doi.org/10.1186/s12909-018-1308-x

105. Schließmann, D., et al., Trainer in a pocket – proof-of-concept of mobile, real-time, foot kinematics feedback for gait pattern normalization in individuals after stroke, incomplete spinal cord injury and elderly patients, *J. Neuroeng. Rehabil.,* 2018, vol. 15, no. 1, pp. 1–15. https://doi.org/10.1186/s12984-018-0389-4

106. Reinkensmeyer, D.J., et al., How a diverse research ecosystem has generated new rehabilitation technologies: review of NIDILRR's rehabilitation engineering research centers, *J. Neuroeng. Rehabil.,* 2017, vol. 14, no. 1, pp. 1–53. https://doi.org/10.1186/s12984-017-0321-3

107. Castelló, V., Traver, V.J., Serrano, B., Montoliu, R., and Botella, C., Assisting therapists in assessing small animal phobias by computer analysis of video-recorded sessions, *Multimed. Tools Appl.,* 2017, vol. 76, no. 20, pp. 21033–21049. https://doi.org/10.1007/s11042-016-3997-7

108. Santos, O.C., Kravcik, M., and Boticario, J.G., Preface to special issue on user modelling to support personalization in enhanced educational settings, *Int. J. Artif. Intell. Educ.,* 2016, vol. 26, no. 3, pp. 809–820. https://doi.org/10.1007/s40593-016-0114-z

109. Wüller, H., Behrens, J., Garthaus, M., Marquard, S., and Remmers, H., A scoping review of augmented reality in nursing, *BMC Nurs.,* 2019, vol. 18, no. 1, pp. 1–11. https://doi.org/10.1186/s12912-019-0342-2

110. Alnusair, A., Zhong, C., Rawashdeh, M., Hossain, M.S., and Alamri, A., Context-aware multimodal recommendations of multimedia data in cyber situational awareness, *Multimed. Tools Appl.,* 2017, vol. 76, no. 21, pp. 22823–22843. https://doi.org/10.1007/s11042-017-4681-2

111. Powell, L., Parker, J., and Harpin, V., What is the level of evidence for the use of currently available technologies in facilitating the self-management of difficulties associated with ADHD in children and young people? A systematic review, *Eur. Child Adolesc. Psychiatry,* 2018, vol. 27, no. 11, pp. 1391–1412. https://doi.org/10.1007/s00787-017-1092-x

112. Campos, J.C., Abade, T., Silva, J.L., and Harrison, M.D., Don't go in there! Using the APEX framework in the design of ambient assisted living systems, *J. Ambient Intell. Humaniz. Comput.,* 2017, vol. 8, no. 4, pp. 551–566. https://doi.org/10.1007/s12652-016-0444-6

113. Merilampi, S., Koivisto, A., and Sirkka, A., Designing serious games for special user groups – design for somebody approach, *Br. J. Educ. Technol.,* 2018, vol. 49, no. 4, pp. 646–658. https://doi.org/10.1111/bjet.12631

114. Terras, M.M., Boyle, E.A., Ramsay, J., and Jarrett, D., The opportunities and challenges of serious games for people with an intellectual disability, *Br. J. Educ. Technol.,* 2018, vol. 49, no. 4, pp. 690–700. https://doi.org/10.1111/bjet.12638

115. Bossavit, B. and Parsons, S., Outcomes for design and learning when teenagers with autism codesign a serious game: a pilot study, *J. Comput. Assist. Learn.,* 2018, vol. 34, no. 3, pp. 293–305. https://doi.org/10.1111/jcal.12242

116. Cano, A.R., Fernández-Manjón, B., and García-Tejedor, Á.J., Using game learning analytics for validating the design of a learning game for adults with intellectual disabilities, *Br. J. Educ. Technol.,* 2018, vol. 49, no. 4, pp. 659–672. https://doi.org/10.1111/bjet.12632

117. Hodge, P., et al., StreetWise: a valid ecology for a serious game in a secure forensic mental health setting, *Procedia Comput. Sci.,* 2015, vol. 63, no. Icth, pp. 252–259. https://doi.org/10.1016/j.procs.2015.08.341

118. Ganzeboom, M., Bakker, M., Beijer, L., Rietveld, T., and Strik, H., Speech training for neurological patients using a serious game, *Br. J. Educ. Technol.,* 2018, vol. 49, no. 4, pp. 761–774. https://doi.org/10.1111/bjet.12640

119. Perry, D., Robinson, J., Cruz, S., Aragon, C., Chowning, J.T., and Peters, M., Game design for bioinformatics and cyberinfrastructure learning: a parallel computing case study, *Concurr. Comput. Pract. Exp.,* 2014, vol. 22, no. 6, pp. 685–701. https://doi.org/10.1002/cpe

120. Leroi, I., Watanabe, K., Hird, N., and Sugihara, T., 'Psychogeritechnology' in Japan: exemplars from a super-aged society, *Int. J. Geriatr. Psychiatry,* 2018, vol. 33, no. 12, pp. 1533–1540. https://doi.org/10.1002/gps.4906

121. Park, J., Mostafa, N.A., and Han, H.J., 'StoryWeb': a storytelling-based knowledge-sharing application among multiple stakeholders, *Creat. Innov. Manag.,* 2020, vol. 29, no. 2, pp. 224–236. https://doi.org/10.1111/caim.12368

122. Sharit, J., et al., The roles of health literacy, numeracy, and graph literacy on the usability of the VA's personal health record by veterans, *J. Usability Stud.,* 2014, vol. 9, no. 4, pp. 173–193.

123. Nunes, F., Verdezoto, N., Fitzpatrick, G., Kyng, M., Grönvall, E., and Storni, C., Self-care technologies in HCI: trends, tensions, and opportunities, *ACM Trans. Comput. Interact.,* 2015, vol. **22**, no. 6. https://doi.org/10.1145/2803173

124. Spiel, K., Frauenberger, C., Keyes, O.S., and Fitzpatrick, G., Agency of autistic children in technology research – a critical literature review, *ACM Trans. Comput. Interact.,* 2019, vol. 26, no. 6. https://doi.org/10.1145/3344919

125. Reynolds, L.M., et al., StreetWise: developing a serious game to support forensic mental health service users' preparation for discharge: a feasibility study, *J. Psychiatr. Ment. Health Nurs.,* 2017, vol. 24, no. 4, pp. 185–193. https://doi.org/10.1111/jpm.12340

126. Savazzi, F., Isernia, S., Jonsdottir, J., Di Tella, S., Pazzi, S., and Baglio, F., Engaged in learning neurorehabilitation: development and validation of a serious game with user-centered design, *Comput. Educ.,* 2018, vol. 125, pp. 53–61. https://doi.org/10.1016/j.compedu.2018.06.001

127. Robertson, J., Macvean, A., Fawkner, S., Baker, G., and Jepson, R.G., Savouring our mistakes: learning from the FitQuest project, *Int. J. Child-Comput. Interact.,* 2018, vol. 16, pp. 55–67. https://doi.org/10.1016/j.ijcci.2017.12.003

128. Adams, A., Hart, J., Iacovides, I., Beavers, S., Oliveira, M., and Magroudi, M., Co-created evaluation: Identifying how games support police learning, *Int. J. Hum. Comput. Stud.,* 2019, vol. 132, pp. 34–44. https://doi.org/10.1016/j.ijhcs.2019.03.009

129. Rodrigues, L.F., Costa, C.J., and Oliveira, A., Gamification: a framework for designing software in e-banking, *Comput. Human Behav.,* 2016, vol. 62, pp. 620–634. https://doi.org/10.1016/j.chb.2016.04.035

130. Françoise, J. and Bevilacqua, F., Motion-sound mapping through interaction: an approach to user-centered design of auditory feedback using machine learning, *ACM Trans. Interact. Intell. Syst.,* 2018, vol. 8, no. 2, pp. 1–30. https://doi.org/10.1145/3211826

131. Kayali, F., et al., Design considerations for a serious game for children after hematopoietic stem cell transplantation, *Entertain. Comput.,* 2016, vol. 15, pp. 57–73. https://doi.org/10.1016/j.entcom.2016.04.002

132. Salomão, R.C.S., Rebelo, F., and Rodríguez, F.G., Defining personas of university students for the development of a digital educational game to learn portuguese as a foreing language, *Procedia Manuf.,* 2015, vol. 3, no. Ahfe, pp. 6214–6222. https://doi.org/10.1016/j.promfg.2015.07.941

133. Ramos-Vega, M.C., Palma-Morales, V.M., Pérez-Marín, D., and Moguerza, J.M., Stimulating children's engagement with an educational serious videogame using lean UX co-design, *Entertain. Comput.,* 2021, vol. 38, no. 3, p. 100405. https://doi.org/10.1016/j.entcom.2021.100405

134. van der Lubbe, L.M., Gerritsen, C., Klein, M.C.A., and Hindriks, K.V., Empowering vulnerable target groups with serious games and gamification, *Entertain. Comput.,* 2021, vol. 38, p. 100402. https://doi.org/10.1016/j.entcom.2020.100402

135. Bennani, S., Maalel, A., and Ben Ghezala, H., Agelearn: ontology-based representation of personalized gamification in e-learning, *Procedia Comput. Sci.,* 2020, vol. 176, pp. 1005–1014. https://doi.org/10.1016/j.procs.2020.09.096

136. Stamm, O., Dahms, R., and Müller-Werdan, U., Virtual reality in pain therapy: a requirements analysis for older adults with chronic back pain, *J. Neuroeng. Rehabil.,* 2020, vol. 7, p. 129. https://doi.org/10.1186/s12984-020-00753-8

137. Spil, T.A.M., Romijnders, V., Sundaram, D., Wickramasinghe, N., and Kijl, B., Are serious games too serious? Diffusion of wearable technologies and the creation of a diffusion of serious games model, *Int. J. Inf. Manag.,* 2021, vol. 58, p. 102202. https://doi.org/10.1016/j.ijinfomgt.2020.102202

138. Teruel, M.A., Navarro, E., González, P., López-Jaquero, V., and Montero, F., Applying thematic analysis to define an awareness interpretation for collaborative computer games, *Inf. Software Technol.,* 2016, vol. 74, pp. 17–44. https://doi.org/10.1016/j.infsof.2016.01.009

139. Bruno, F., et al., Virtual dives into the underwater archaeological treasures of South Italy, *Virtual Reality,* 2018, vol. 22, no. 2, pp. 91–102. https://doi.org/10.1007/s10055-017-0318-z

140. Koutsabasis, P. and Vosinakis, S., Kinesthetic interactions in museums: conveying cultural heritage by making use of ancient tools and (re-) constructing artworks, *Virtual Reality,* 2018, vol. 22, no. 2, pp. 103–118. https://doi.org/10.1007/s10055-017-0325-0

141. Speake, H., Copeland, R.J., Till, S.H., Breckon, J.D., Haake, S., and Hart, O., Embedding physical activity in the heart of the NHS: the need for a whole-system approach, *Sport. Med.,* 2016 vol. 46, no. 7, pp. 939–946. https://doi.org/10.1007/s40279-016-0488-y

142. Sigala, M., The application and impact of gamification funware on trip planning and experiences: the case of TripAdvisor's funware, *Electron. Mark.,* 2015,

vol. 25, no. 3, pp. 189–209.
https://doi.org/10.1007/s12525-014-0179-1

143. Bonet, N., von Barnekow, A., Mata, M.T., Gomar, C., and Tost, D., Three-dimensional game-based cardiopulmonary bypass training, *Clin. Simul. Nurs.,* 2021, vol. 50, pp. 81–91.e1.
https://doi.org/10.1016/j.ecns.2020.08.007

144. Zhang-Kennedy, L. and Chiasson, S., A systematic review of multimedia tools for cybersecurity awareness and education, *ACM Comput. Surv.,* 2021, vol. 54, no. 1, pp. 1–39.
https://doi.org/10.1145/3427920

145. Schulz, R., Smaradottir, B., Prinz, A., and Hara, T., User-centered design of a scenario-based serious game: game-based teaching of future healthcare, *IEEE Trans. Games,* 2020, vol. 12, no. 4, pp. 376–385.
https://doi.org/10.1109/TG.2020.3033437

146. Agbo, F.J., Oyelere, S.S., Suhonen, J., and Laine, T.H., Co-design of mini games for learning computational, *Educ. Inf. Technol.,* 2021, vol. 26, no. 5, pp. 5815–5849.
https://doi.org/10.1007/s10639-021-10515-1

147. Woolford, K. and Dunn, S., Experimental archaeology and games: challenges of inhabiting virtual heritage, *J. Comput. Cult. Herit.,* 2013, vol. 6, no. 4, pp. 1–15.
https://doi.org/10.1145/2532630.2532632

148. Gilbert, S.B., Jang, W., Garcia, A., Krone, N., Ramezani, M., and Doty, K., Re-Solution-Katrina edition: moving a face-to-face game online, *Proc. Hum. Factors Ergon. Soc.,* 2017, vol. 61, no. 1, pp. 356–360.
https://doi.org/10.1177/1541931213601571

149. Wasil, A.R., Venturo-Conerly, K.E., Shingleton, R.M., and. Weisz, J.R, A review of popular smartphone apps for depression and anxiety: assessing the inclusion of evidence-based content, *Behav. Res. Ther.,* 2019, vol. 123, p. 103498.
https://doi.org/10.1016/j.brat.2019.103498

150. Li, Q., Enactivism and teacher instructional game building: an inquiry of theory adoption and design consideration, *Educ. Technol. Res. Dev.,* 2018, vol. 66, no. 6, pp. 1339–1358.
https://doi.org/10.1007/s11423-018-9584-z

151. Lorenz, T., Weiss, A., and Hirche, S., Synchrony and reciprocity: key mechanisms for social companion robots in therapy and care, *Int. J. Soc. Robot.,* 2016, vol. 8, no. 1, pp. 125–143.
https://doi.org/10.1007/s12369-015-0325-8

152. Money, A. and Coughlan, J., Team-taught versus individually taught undergraduate education: a qualitative study of student experiences and preferences, *High. Educ.,* 2016, vol. 72, no. 6, pp. 797–811.
https://doi.org/10.1007/s10734-015-9976-5

153. Corrêa Souza, A.C., Nunes, F.L.S., and Delamaro, M.E., An automated functional testing approach for virtual reality applications, *Software Test. Verif. Reliab.,* 2018, vol. 28, no. 8, pp. 1–31.
https://doi.org/10.1002/stvr.1690

154. Pyae, A., Liukkonen, T., Saarenpää, T., Luimula, M., Granholm, P., and Smed, J., When Japanese elderly people play a Finnish physical exercise game: a usability study, *J. Usability Stud.,* 2016, vol. 11, no. 4, pp. 131–152.

155. Konstantakis, M. and Caridakis, G., Adding culture to UX: UX research methodologies and applications in cultural heritage, *J. Comput. Cult. Herit.,* 2020, vol. 13, no. 1, pp. 1–17.
https://doi.org/10.1145/3354002

156. Tao, G., Garrett, B., Taverner, T., Cordingley, E., and Sun, C., Immersive virtual reality health games: a narrative review of game design, *J. Neuroeng. Rehabil.,* 2021, vol. 18, no. 1, pp. 1–21.
https://doi.org/10.1186/s12984-020-00801-3

157. Pedraza-Hueso, M., Martín-Calzón, S., Díaz-Pernas, F.J., and Martínez-Zarzuela, M., Rehabilitation using kinect-based games and virtual reality, *Procedia Comput. Sci.,* 2015, vol. 75, no. Vare, pp. 161–168.
https://doi.org/10.1016/j.procs.2015.12.233

158. Fonseca, D. and García-Peñalvo, F.J., Interactive and collaborative technological ecosystems for improving academic motivation and engagement, *Univers. Access Inf. Soc.,* 2019, vol. 18, no. 3, pp. 423–430.
https://doi.org/10.1007/s10209-019-00669-8

159. Bellotti, F., Berta, R., De Gloria, A., D'Ursi, A., and Fiore, V., A serious game model for cultural heritage, *J. Comput. Cult. Herit.,* 2012, vol. **5**, no. 4.
https://doi.org/10.1145/2399180.2399185

160. Tong, T., Chignell, M., and Sieminowski, T., Case study: a serious game for neurorehabilitation assessment, *Procedia Comput. Sci.,* 2015, vol. 69, pp. 125–131.
https://doi.org/10.1016/j.procs.2015.10.013

161. Valladares-Rodriguez, S., Fernández-Iglesias, M.J., Anido-Rifón, L., Facal, D., Rivas-Costa, C., and Pérez-Rodríguez, R., Touchscreen games to detect cognitive impairment in senior adults. A user-interaction pilot study, *Int. J. Med. Inform.,* 2019, vol. 127, pp. 52–62.
https://doi.org/10.1016/j.ijmedinf.2019.04.012

162. Luz, S., Masoodian, M., Cesario, R.R., and Cesario, M., Using a serious game to promote community-based awareness and prevention of neglected tropical diseases, *Entertain. Comput.,* 2016, vol. 15, pp. 43–55.
https://doi.org/10.1016/j.entcom.2015.11.001

163. Hidalgo-Mazzei, D., et al., OpenSIMPLe: a real-world implementation feasibility study of a smartphone-based psychoeducation programme for bipolar disorder, *J. Affect. Disord.,* 2018, vol. 241, pp. 436–445.
https://doi.org/10.1016/j.jad.2018.08.048

164. Martinez-González, C.L., Camargo-Fajardo, M.C.C., Segura-Medina, P., and Quezada-Bolaños, P., Therapeutic patient education with learning objects improves asthma control in Mexican children, *J. Med. Syst.,* 2020, vol. 44, no. 4.
https://doi.org/10.1007/s10916-020-1539-3

165. Benito-Santos, A., Dorn, A., Gómez, A.G.L., Palfinger, T., Sánchez, R.T., and Wandl-Vogt, E., Playing design: a case study on applying gamification to construct a serious game with youngsters at social risk, *J. Comput. Cult. Herit.,* 2021, vol. 14, no. 2.
https://doi.org/10.1145/3427380

166. Kiili, K., De Freitas, S., Arnab, S., and Lainema, T., The design principles for flow experience in educational games, *Procedia Comput. Sci.,* 2012, vol. 15,

pp. 78–91.
https://doi.org/10.1016/j.procs.2012.10.060

167. Ghanbari, H., Similä, J., and Markkula, J., Utilizing online serious games to facilitate distributed requirements elicitation, *J. Syst. Software,* 2015, vol. 109, pp. 32–49.
https://doi.org/10.1016/j.jss.2015.07.017

168. De Troyer, O. and Janssens, E., Supporting the requirement analysis phase for the development of serious games for children, *Int. J. Child-Comput. Interact.,* 2014, vol. 2, no. 2, pp. 76–84.
https://doi.org/10.1016/j.ijcci.2014.05.001

169. Sobrino-Duque, R., Martínez-Rojo, N., Carrillo-de-Gea, J.M., López-Jiménez, J.J., Nicolás, J., and Fernández-Alemán, J.L., Evaluating a gamification proposal for learning usability heuristics: Heureka, *Int. J. Hum. Comput. Stud.,* 2022, vol. 161, p. 102774.
https://doi.org/10.1016/j.ijhcs.2022.102774

170. Howes, S.C., Charles, D., Pedlow, K., Wilson, I., Holmes, D., and McDonough, S., User-centred design of an active computer gaming system for strength and balance exercises for older adults, *J. Enabling Technol.,* 2019, vol. 13, no. 2, pp. 101–111.
https://doi.org/10.1108/JET-12-2018-0057

171. Harrington, M.C.R., The virtual trillium trail and the empirical effects of freedom and fidelity on discovery-based learning, *Virtual Real.,* 2012, vol. 16, no. 2, pp. 105–120.
https://doi.org/10.1007/s10055-011-0189-7

172. Bontchev, B., Antonova, A., Terzieva, V., and Dankov, Y., "Let us save Venice' – an educational online maze game for climate resilience, *Sustainability,* 2022, vol. 14, no. 1.
https://doi.org/10.3390/su14010007

173. Shohieb, S.M., Doenyas, C., and Elhady, A., Dynamic difficulty adjustment technique-based mobile vocabulary learning game for children with autism spectrum disorder, *Entertain. Comput.,* 2022, vol. 42, p. 100495.

174. Cornejo, R., et al., Serious games for basic learning mechanisms: reinforcing Mexican children's gross motor skills and attention, *Pers. Ubiquitous Comput.,* 2021, vol. 25, no. 2, pp. 375–390.
https://doi.org/10.1007/s00779-021-01529-0

175. Bisadi, M. and Chua, A.Y.K., DGIST: a digital game for international students' adjustment, *Interact. Technol. Smart Educ.,* 2014, vol. 11, no. 1, pp. 15–31.
https://doi.org/10.1108/ITSE-10-2013-0023

176. Ng, Y.Y.N., Khong, C.W., and Nathan, R.J., Evaluating affective user-centered design of video games using qualitative methods, *Int. J. Comput. Games Technol.,* 2018, no. 2, pp. 1–13.
https://doi.org/10.1155/2018/3757083

177. Ali, Z. and Usman, M., A framework for game engine selection for gamification and serious games, *Proc. Future Technologies Conf. FTC 2016,* San Francisco, 2016, pp. 1199–1207.
https://doi.org/10.1109/FTC.2016.7821753

178. Panach, J.I., Pederiva, I., España, S., and Pastor, Ó., Generación Automática de Interfaces a Partir de Patrones Estructurales de Tareas.

179. Vanden Abeele, V., et al., P-III: a player-centered, iterative, interdisciplinary and integrated framework for serious game design and development, *Commun. Comput. Inf. Sci.,* 2012, vol. 280 CCIS, pp. 82–86.
https://doi.org/10.1007/978-3-642-33814-4_14

180. Gonzalez Sánchez, J.L., Padilla Zea, N., Gutierrez, F.L., and Cabrera, M.J., De la Usabilidad a la Jugabilidad: Diseno de Videojuegos Centrado en el Jugador, *Proc. 9th Congr. Int. Interaccion,* Albacete, June 9–11, 2008, pp. 1–10.

181. Kuznetsov, M.B., UML model transformation and its application to MDA technology, *Program. Comput. Software,* 2007, vol. **33**, pp. 44–53.
https://doi.org/10.1134/S0361768807010069

182. Gorshkova, E.A., Novikov, B.A., Belov, D.D., Gurov, V.S., and Spiridonov, S.V., A UML-based modeling of web application controller, *Program. Comput. Software,* 2005, vol. 31, pp. 29–33.
https://doi.org/10.1007/s11086-005-0010-z