Automatic Code Generation of User-Centered Serious Games: A Systematic Literature Review

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***Abstract*— This paper reviews the literature on automatic code generation of user-centered serious games. As an early literature review led us to just one paper, we decided to break the study in two parts: one study about model driven engineering of serious games, and another study about user-centered serious games. This paper presents these two studies, where a total of 123 works were analyzed. The overall conclusion is that work still needs to be done to combine user-centered serious games and automatic code generation in order to escape from ad-hoc solutions that usually are time-consuming and error-prone.**

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

I. INTRODUCTION

The increasing complexity of systems development creates the need for tools to improve productivity in terms of time, cost, and quality [1]. 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 [2]. 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. In this paper we are interested particularly in studying the links of MDE/ACG with User-Centered Serious Games.

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 [3]. SGs mix, with pedagogical principles, the engaging and motivational characteristics of video games (history, character design, game rules, to name a few [4]), and touch on a wide range of subjects such as science, healthcare, business practices, and history [5]. Despite the efforts made in this area, some challenges still remain, specifically: 1) developing better SGs, with 2) less budget and resources, and 3) on time [6]. This is where MDE and ACG can propose a solution.

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 [7]. 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.

Our overall work is then interested in the (semi-) automatic generation of user-centered serious games. As a pre-requisite, it was necessary to analyze the works in this area, so we conducted a preliminary systematic literature review. To our surprise we only found one paper [6] about the topic. In that paper, the authors introduce SEGA-ARM, a metamodel to support the design of serious games for auditory rehabilitation, considering the user's capabilities, the context of use, and concepts related to the user centered design of serious games. Two game prototypes were developed to validate the viability of the application of the metamodel for the development of serious games and to point out its reuse and extension. Thus, the paper can then be considered as pioneer in this field.

As we were conscious of the vast literature on MDE/ACG and on serious games, we then decided to break our systematic literature review in two parts: one about model driven engineering of serious games, and another about user-centered serious games. This paper presents these two parts, where a total of 123 works was analyzed. The overall conclusion is that work still need to be done to combine user-centered serious games and automatic code generation to escape from ad-hoc solutions that are usually time-consuming and error-prone.

The document is structured as follows: Section II introduces the research method that has been followed. Section III presents the results of the first search string. Section IV presents the results of the second search string. Section V discusses our findings. Finally, section VI concludes this paper.

II. RESEARCH METHOD

The systematic review of the literature is based on the guidelines advanced [8] and inspired by proposals such as that of [9].

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

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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.

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

- What are the works on automatic code generation and serious games?
- What are the works on user-centered design and serious games?
- How could you combine automatic code generation with serious user-centered games?

Selection 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. The three criteria for inclusive are described below:

- Several online journal databases were selected to search for literature. The online journal databases a) Science Direct, b) Springer Link, c) Wiley Online Library, d) Emerald, e) ACM Digital Library & f) IEEE Xplore were considered.
- This paper analyzes the articles published from 2014 to 2020. Articles falling within this span of time were included. The reason for selecting this period was that we thought it was important to cover the last 6 years of research related to these topics. By adhering to these criteria, the latest research produced and published in research journals were also reviewed.
- This paper only covers articles from scientific journals. Other publications such as conferences, unpublished work, newspapers, books, doctoral and master's theses, were not included, as researchers publish their impact results in academic journals to obtain to disseminate the conclusions of their studies. Journal articles indicate a higher level of research and that is the reason only papers from journals were filtered.

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.

III. MODEL-DRIVEN ENGINEERING – SERIOUS GAMES

A. *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: 28, b) Springer Link: 97, c) Wiley Online Library: 6, d) Emerald: 6, e) ACM Digital Library: 25, and f) IEEE Xplore: 7, which amounts to a total of 169 papers.

The criteria of the time (2014-2020) was also applied to know the latest research related to the topic of the search string. After the proper filters were applied, a total of 30 papers out of the 169 were discarded. The results were the following: a) Science Direct: 26, b) Springer Link: 72, c) Wiley Online Library: 4, d) Emerald: 6, e) ACM Digital Library: 18, and f) IEEE Xplore: 4. After excluding the results regarding the fact that they are only from journals, the total found was 39 of the 169.

To finalize the selection of the articles that we considered for this research, a quick search were 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. Nine systematic searches were discarded. Additionally, eight articles that did not have a direct relation were also eliminated, leaving us only with 22 works directly related. Fig. 1 presents a summary of how the application of the method was followed.

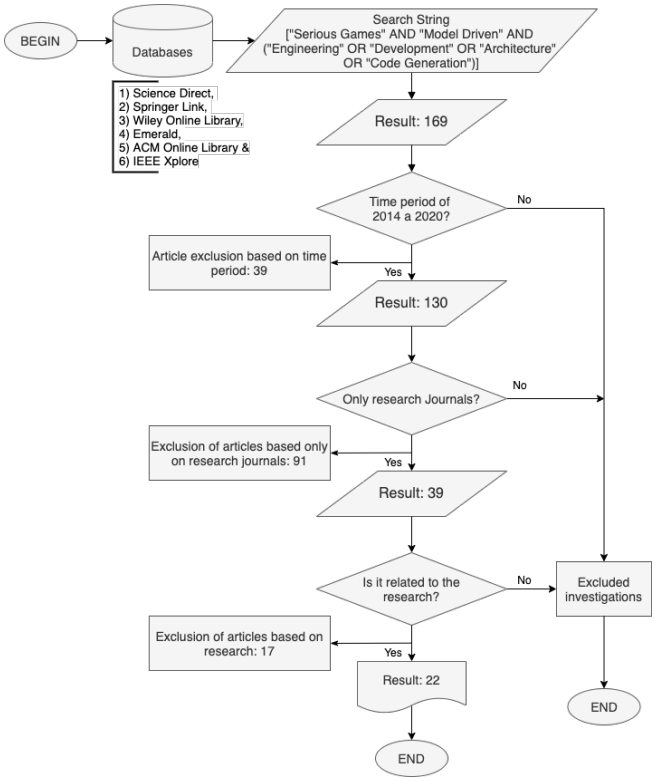

Figure 1. Presentation of the application of the method

B. *Quantitative analysis*

Below is a review of the number of articles, per year of publication, on Serious Games and Model-Driven Engineering or Model-Driven Development or Model Driven Architecture or Model-Driven Code Generation published between from 2014 to 2020. The number of articles in 2014,

2015 and 2016 was low as only three were published. The number of articles in 2017 had an increase of 100% compared to 2014, 2015 and 2016, with 6 papers. In 2018 and 2019, again, production is low, with only 3 papers each year. For the fifth month of 2020, only one article related to the search string was published.

The article presents 22 papers related to the search string ["Serious Games" and "Model-Driven" and ("Engineering" or "Development" or "Architecture" or "Code Generation")] Six online databases to search the articles were used. The results were as follows: a) Science Direct: 7, b) Springer Link: 11, c) Wiley Online Library: 2, and d) ACM Digital Library: 2. On the basis of these results, Emerald and IEEE Xplore were discarded because they did not present results. Springer Link accounts for 50% of the total. In second place, Science Direct amounts for 32%. In third place, ACM Digital and Wiley account for 9% each. This is illustrated in represented in fig. 2.

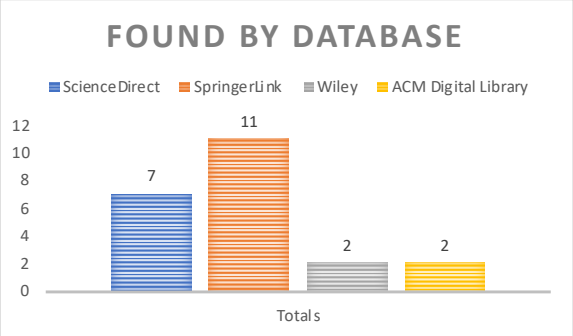

Figure 2. Papers by Database Online.

The journal articles were published in 18 journals related to the search string ["Serious Games" and "Model-Driven" and ("Engineering" or "Development" or "Architecture" or "Code Generation")]. Most of these were computer-related, although education and health related journals were also found. The journal "Multimedia Tools and Applications" published most of the articles related to our search string; that is 4 papers. " Entertainment Computing" contributed with 2 papers. The remaining 16 other journals also published papers related to the search string.

C. Qualitative analysis

We found an interesting amount of papers related to the topic: 22 papers were directly related. 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.

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, [10], [11] & [12]. 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, [13], [14], [15], [16], [17], [18], [19], [20].

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, [21], [22].

Finally, In [23] 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 [24] and [25] 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.

2. Application Domains

For this classification works that have developed a serious game that was guided in the model-driven engineering are presented. For the end of this classification, the papers present alternatives of serious games that are centered on the use of the application, not on the development of the same. In this classification, only the serious game with its characteristics is presented but details of the development are not described.

Educational. In [26] 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 in the course of using the video game.

Rehabilitation. In [27] 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.

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 [28] and [29], 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 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 [30].

Another interesting research is [31] where the performance of two games that where evaluated is presented. The results of the game engine variant were similar to those of the purpose-built game, where both games significantly predicted the performance in the three cognitive skills and were sensitive to the effects of age. Performance in both games was not significantly affected by tablet size or method of entry. These results support the conclusions that serious games can be a tool to evaluate the cognitive aspect of the user, at low-cost way and without losses.

TABLE I. CLASSIFICATION OF WORKS

CLASSIFICATION	PAPERS
Model-Driven Engineering of Serious Games	[10][11][12][13][14][15][16][17] [18][19][20][21][22][23][24][25]
Application Domains	[26][27]
Evaluate Gameplay	[28][29][30][31]

Table I 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.

IV. USER-CENTERED DESIGN – SERIOUS GAMES

A. 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: 74, b) Springer Link: 75, c) Wiley Online Library: 29, d) Emerald: 18, d) ACM Digital Library: 189, and e) IEEE Xplore: 21. In total 406 articles were found.

The criteria of the time (2014-2020) was applied to know the latest research related to the topic of the search string. In total, the 406 articles were narrowed to 325. The results were the following: a) Science Direct: 66, b) Springer Link: 58, c) Wiley Online Library: 26, d) Emerald: 18, e) ACM Digital Library: 142, and f) IEEE Xplore: 15.

After eliminating those articles that were not published in journals, the total was reduced to 115 out of the 325.

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.

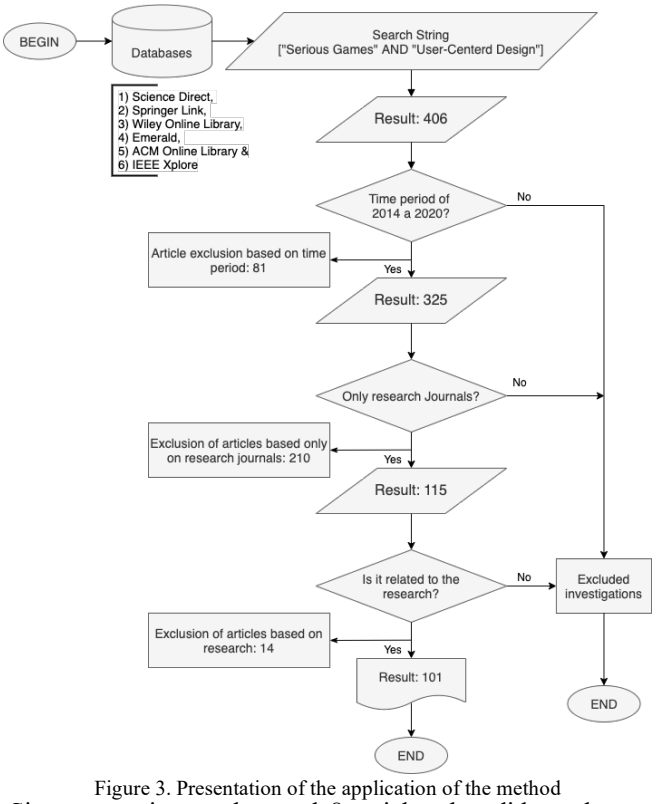

Figure 3. Presentation of the application of the method

Six systematic searches and 8 articles that did not have a direct relation were eliminated, leaving us only with 101 pieces of directly related to the topic. In fig. 3 it is possible to identify a summary of how the application of the method was followed.

B. *Quantitative analysis*

The number of articles per year of publication on serious games and user-centered design has grown in our range from 2014 to 2020. The number of articles in 2014 was 10. In comparison with 2015, there was an increase of 70%, with 17 articles published. The number of articles in 2016 was 13 and in 2017: 11, which shows had a decline. However, 2018 there was an increase, as the highest number of research contributions was 22. 2019 shows a decrease but it is better than in 2015 and 2016, with 18 papers. For the first five months of 2020, five articles related to the search string were found.

The article presents 101 papers related to the search string ["Serious Game" and "User-Centered Design"]. Six online databases to search the articles were used. The results were as follows: a) Science Direct: 45, b) Springer Link: 35, c) Wiley Online Library: 14, and, d) ACM Digital Library: 7. On the basis of these results, Emerald and IEEE Xplore were discarded because they did not present results, Science Direct accounts for 45% of the total. In second place, Springer Link accounts for 35%. In third place, Wiley Online accounts for 13%, and in fourth place, ACM digital accounts for 7%. This is illustrated in fig. 4.

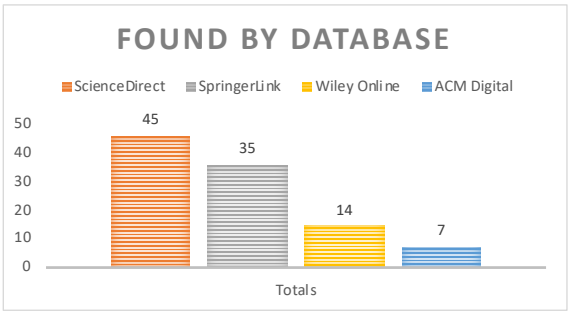

Figure 4. Papers by Database Online.

The journal articles are divided into 65 journals that published articles related to the search string ["Serious Game" and "User-Centered Design"]. Most of these were computer-related; however, education and health-related journals were also found. “Entertainment Computing” published most of the articles related to our search string, with eight papers. “British Journal of Educational Technology” comprises six papers, and “International Journal of Human-Computer Studies”, “Multimedia Tools and Applications” and “Procedia Computer Science” supplied four papers each one. There were 59 other journals that also published papers related to the search string.

C. *Qualitative analysis*

More than 101 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.

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 [20], [32], [33], [34], [35], [36], [37], and [38].

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 [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], and [52] 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.

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 the 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 [12],[27],[53], [54], [55], [56], and [57]. Likewise, there is a project [58] 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 [59], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [71], [72], [73], [74], [75], [76], [77], [78], [79], [80], [81], [82], [83], [84], [85], [86], [87], [88], [89], [90], [91], [92], [93], [94], [95], [96], [97], [98], [99], [100], [101], [102], [103], [104], [105], [106], [107], and [108] 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.

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 [54], [55], [60], [61], [62], [63], [65], [70], [72], [74], [78], [80], [81], [85], [88], [89], [91], [92], [95], [97], [99], [100], [109], [110], [111], [112], and [113] where that is the principal objective.

Rehabilitation: Works such as [114] and [115] 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 [116], [117], [118], [119], and [120] 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 [101], [66], [71], [83], [90], [93], [94], [96], and [98].

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 implement [121] and [122].

Similarly, we can realize that some considerable overlapping still exist 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.

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.

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 [102], [103], [104], [105], and [106].

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 [123], [124], [125], [126], [127], [128], and [129].

The classifications can vary and that there may be very few projects that only fit in a given classification at present. The integration of user-centered design is considered an essential part of the integration in projects of any kind, so the attempt of researchers to generate serious game applications for a user is no less valuable. The same goes for the evaluations that are presented to improve aspects that meet the requirements of the user.

Table II presents the group of articles respectively classified. 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.

TABLE II. CLASSIFICATION OF WORKS

CLASSIFICATION	PAPERS	
Application Model or Framework	[20][32][33][34][35][36][37][38][39][40][41] [42][43][44][45][46][47][48][49][50][51][52]	
User Model	[12][27][53][54][55][56][57][58][59][60][61] [62][63][64][65][66][67][68][69][70][71][72] [73][74][75][76][77][78][79][80][81][82][83] [84][85][86][87][88][89][90][91][92][93][94] [95][96][97][98][99][100][101][102][103] [104][105][106][107][108]	
Application Domains	Learning	[54][55][60][61][62][63] [65][70][72][74][78][80] [81][85][88][89][91][92] [95][97][99][100][109] [110][111][112][113]
	Rehabilitation	[114][115]
	Diagnostic	[116][117][118][119][120]
	Selecting	[66][71][83][90][93][94] [96][98][101]
	User-centered design	[121][122]
Evaluation of User-Centered Design	[102][103][104][105][123][124][125][126] [127][128][129]	

V. 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. We also sought to shed light how these applications have come under the scrutiny of user-centered design, as well as highlight 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. We must also bear in mind that the tools that use the model-driven and try to be useful do not have user-centered design patterns, so it makes them complicated to use.

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 are 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.

We need new proposals for serious games, including a methodology for their development that incorporates user-centered design, new ways to evaluate the gameplay in the end player, which does not focus only on usability, and new tools based on model-driven that present a user-centered design and that are an agile development.

VI. Conclusion

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

We need a tool that follows the model and provides a first prototype of serious game that contemplates the user-centered design, shortening the development and investment times.

Considering that for future works, we will have to work on a Model-Driven Game Development for the process of developing serious games. However, this must incorporate the part of the design centered in the user, for an interaction of the end user, offering the playability that is needed, without leaving aside the educational and learning part that must be present in the serious games.

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