State of the art on the conceptual modeling of serious games through a systematic mapping of the literature

Estado del arte sobre el modelado conceptual de juegos serios mediante un mapeo sistemático de la literatura

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Abstract

Serious games are those games whose objective is to stimulate learning or the acquisition of knowledge or a skill. Currently, there is a trend in the market towards the generation of this type of games. Given the importance of conceptualizing the domain of a problem and its solution, this paper presents the results of a systematic mapping of the literature, Systematic Mapping Study (SMS), with the purpose of identifying the state of the art and discovering the existing contributions regarding the conceptual modeling of serious games. A search was carried out in *Scopus, IEEE Xplore* and *ACM* digital libraries from January 2010 to June 2021. Of a total of 558 articles identified, 31 primary studies were analyzed. It was evidenced that the use of UML prevails for the modeling of serious games, mainly for class and activity diagrams, together with other languages such as *UP4EG, DSML, Deterministic Finite Automaton (DFA), Discrete Event System Specification (DEVS)* and *Fuzzy Inference Systems (FIS).* Thirty percent of the primary studies propose a framework and another 30% propose a development methodology. Most of these frameworks do not specify how to perform conceptual modeling.

Keywords: conceptual modeling, serious games, systematic mapping of literature.

Resumen

Los juegos serios son aquellos juegos cuyo objetivo es estimular el aprendizaje o la adquisición de un conocimiento o una habilidad. Actualmente, existe una tendencia en el mercado hacia la generación de este tipo de juegos. Dada la importancia de conceptualizar el dominio de un problema y su solución, este trabajo presenta los resultados de un mapeo sistemático de la literatura, *Systematic Mapping Study* (SMS), con el propósito de identificar el estado del arte y descubrir los aportes existentes sobre el modelado conceptual de los juegos serios. Se realizó una búsqueda en bibliotecas digitales *Scopus*, IEEE Xplore y *ACM* desde enero de 2010 hasta junio de 2021. De un total de 558 artículos identificados, se analizaron 31 estudios primarios. Se evidenció que prevalece el uso de UML para el modelado de juegos serios, principalmente para diagramas de clases y actividades, junto con otros lenguajes como *UP4EG*, DSML, *Deterministic Finite Automaton (DFA), Discrete Event System Specification (DEVS)* y *Fuzzy Inference Systems (FIS).*

Palabras claves: modelado conceptual, juegos serios, mapeo sistemático de la literatura.

1. Introduction

This article is an extension of the article presented at CACIC 2021 [1] which was selected among the best articles. Elements of the review protocol and some additional findings from the SMS are incorporated into this article.

In order to provide some background for this work, a number of concepts should first be defined. First, a conceptual model is a concise and deliberate consolidation of a set of concepts presented by means of terms in a predefined linguistic format [2]. Another approach allows us to interpret conceptual modeling as a database design and requirements analysis technique. As a requirements analysis technique, it helps to identify problems in requirements before starting the development thus avoiding unnecessary costs. As a database design technique, it makes it possible to abstractly represent the relevant concepts and facts of the problem domain and, subsequently, to transform them into a specific database scheme [3].

The system model is a conceptualization of the problem domain and its solution. The model focuses on the real world: identifying, classifying, and

abstracting the elements that constitute the problem and organizing them in a formal structure. Abstraction is one of the main techniques with which the human mind manages complexity. By hiding what is irrelevant, a complex system can be reduced to something understandable and manageable. When it comes to software, it is extremely useful to abstract away from the technological details of implementation and deal with domain concepts as directly as possible. In this way, the model of a system provides a means of communication and negotiation between users, analysts and developers that hides or minimizes the aspects related to the implementation technology [4].

Another important concept is that of serious games. Michael *et al*. [5] define the term "serious game" as a way of combining video games and education, where the main objective is education (in any of its forms), and whose main components are objectives, rules, challenges and interaction. Serious games enable another mechanism for teaching and learning, while extending the training objectives and generating not only conditions for the player (student) to learn, but also to apply and demonstrate what they have learned.

Serious games are those whose main objective is not focused on fun, but on learning or acquiring knowledge or skills. Today, they are used for the acquisition of knowledge within the military, political, business, health and education fields. This "serious game concept seeks to enhance learning, the stimulation of critical thinking, training, digital literacy, changes in attitude and generation of emotions, thus going beyond the playful component of games" [6]. It should be noted that "...active learning is also promoted, and training is provided in complementary skills such as decision-making, teamwork, social skills, leadership and collaboration..." [7].

Over the last few decades, methodologies aimed at the creation of serious games have been developed in specific settings. Among them, we can mention EMERGO as a guide for the development of scenario-based games (proposed in 2008); and the methodology based on industrial models dealing with pedagogic engineering, oriented to developments based on educational models aimed at teaching educational competencies (2010). Finally, we can mention the methodologies for the development of serious games aimed at the treatment of patients with mental disorders and language rehabilitation in children with cochlear implants, among others [8].

The taxonomy of serious games components has been studied by various authors in a wide range of publications, among which Bloom's Updated Taxonomy stands out. Together with this taxonomy, Carvalho *et al*. [9] point out that there are differences between Gaming Components, Learning Components and Instructional Components since each of them has specific actions, tools and goals. In particular, Learning Components are the most relevant in serious games modeling. Kolb's Experiential Learning Cycle (1984), which incorporates a constructive approach from the pedagogical point of view, and Fink's Taxonomy of Significant Learning (2003), whose objectives focus on the transfer of abilities, such as critical thinking and creativity, can be used to supplement Bloom's Updated Taxonomy [9].

This article is written within the framework of the Conceptual Modeling Seminar of the Master's Degree in Information Systems Engineering of Facultad Regional Buenos Aires, Universidad Tecnológica Nacional. The choice of the theme has been motivated by the topics of interest in the area of "Advanced and multidisciplinary applications" proposed in the 40th edition of the International Conference on Conceptual Modeling (ER 2021) [10]. The article presents the development of a systematic literature mapping (SMS) to analyze the state of the art and identify existing contributions in relation to the conceptual modeling of serious games. To perform the SMS, the guidelines proposed by Kitchenham *et al*. [11] and by Petersen *et al.* [12] were followed.

The article is structured as follows: Section 2 describes the planning of the SMS. Section 3 describes its execution. The results are presented in Section 4. In Section 5, an analysis of the threats to validity is presented and, finally, in Section 6, the conclusions are presented.

2. Planning of SMS

This section presents the definition of the SMS protocol: research questions (RQ), search strategy, study selection, selection criteria and process, extraction form, and data synthesis process.

The objective of this SMS is to answer the following research question (RQ): *What are the characteristics of the conceptual modeling of serious games?* This main question is broken down into a set of sub-questions (RQ1-5), which are presented in Table 1 along with their motivation.

Table 1. Research questions (RQs) and motivation.

Question (RQ)	Motivation
RQ1: What contributions does it make regarding the conceptual modeling of serious games?	Find out and understand what kind of contributions they provide in terms of conceptual modeling.
RQ2: In what fields are serious games used?	Identify the area where serious games have a greater prevalence
RQ3: Which is the Modeling	Determine the modeling

Question (RQ)	Motivation
Language used in serious game projects?	language used to manage the modeling of a serious game.
RQ4: What diagrams are considered for modeling in serious game projects?	Identify which diagrams are used for modeling a serious game.
RQ5: What are the types of research found in the articles?	Evaluation, philosophical, solution proposal, validation, personal experience, opinion [13].

An automatic search in the *ACM, IEEE Xplore* and *Scopus* digital libraries and platforms was conducted as they are the most widely used libraries in the field of Software Engineering, considering conference articles and journal articles. The search was performed from January 2010 to June 2021.

For the construction of the search string, the main terms "serious games" and "conceptual modeling" were considered, including their alternative terms. The resulting search string is:

(("serious game" or "serious games" or "sg") and ("concept" or "conceptual modeling" or "conceptual modelling"))*

The inclusion and exclusion criteria used for the article selection process are presented in Table 2.

The study selection process consisted of the following steps: 1) performing the search in the defined sources by using the string in the title and/or in the abstract, 2) eliminating duplicate articles, 3) applying the inclusion and exclusion criteria to the title, abstract and keywords, 4) applying the inclusion and exclusion criteria to the full text. This process allowed the selection of the primary studies that were analyzed to answer the research questions (RQs) formulated.

Table 2. Inclusion and exclusion criteria.

Inclusion criteria
I1. Given the case in which several articles of the same author focus on the same research, the most complete and recent article will be considered.
I2. Articles in English
I3. Articles published between January 2010 and June 2021.
I4. Articles that contain prospect strings in the title, keywords and/or abstract.
Exclusion criteria
E1. Articles whose perspective is not in the field of software
E2. All gray literature, namely: technical reports, theses, power point presentations, among others.
E3. Articles with no access.
E4. Articles whose content does not focus on conceptual modeling.
E5. Duplicate articles or partial versions when there is a final version.

To answer each of the research questions (RQs), a classification scheme (see Table 3) and a data extraction form (see Table 4) were defined. A thematic synthesis is used based on the classification scheme that will be represented through tables and graphs.

The review protocol was created by the first four authors and revised by the last two authors.

3. Conducting of SMS

This section presents the search performed in the digital libraries and platforms, and the selection of primary studies according to what is defined in the SMS review protocol.

The search string was applied in the libraries with some necessary adjustments depending on the particularities of each one (see Table 5, Table 6 and Table 7).

The first two authors, together with the author before the last one, made the selection of the primary papers by applying the process of paper selection defined in the protocol. In parallel, the third and fourth authors, together with the last author, replicated the selection process and obtained a set of primary papers. The two sets of primary papers were checked by all authors. Discrepancies were discussed in order to determine whether it was appropriate to include a particular paper or not. Figura 1 shows the article search and selection process.

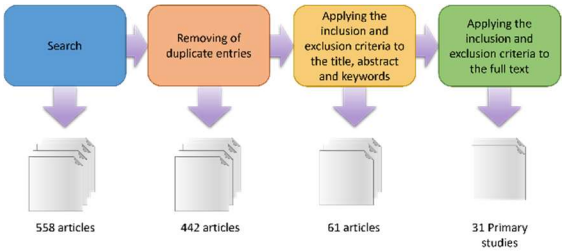

Fig. 1. Article search and selection process.

Of a total of 558 articles found, 31 primary studies were analyzed. The list of the studies analyzed is presented in Table 8.

Table 3. Classification schemes of primary studies.

Dimension	Categories
Contribution.	Methodology, procedure, framework, tool, technique, pattern, others.
Fields	Education, medicine, engineering, military, others, not mentioned.
Modeling Language	UML, UP4EG, DSML, not mentioned, others.
Diagrams.	Domain diagram, communication diagram, state diagram, sequence

Dimension	Categories
	diagram, activity diagram, component diagram, class diagram, object diagram, not mentioned, others.
Types of Research	Evaluation, philosophical, solution proposal, validation, personal experience, opinion [13].

Table 4. Data extraction form.

Metadata	Paper ID, year, title, authors, type of publication (journal or conference), country, keywords.
QI / Dimension	**Categories**
RQ1 / Contribution.	Methodology, procedure, framework, tool, technique, pattern, others.
RQ 2 / Fields	Education, medicine, engineering, military, others, not mentioned.
RQ 3 / Modeling Language	UML, UP4EG, DSML, not mentioned, others.
RQ 4 / Diagrams.	Domain diagram, communication diagram, state diagram, sequence diagram, activity diagram, component diagram, class diagram, object diagram, not mentioned, others.
RQ 5 / Types of Research	Evaluation, philosophical, solution proposal, validation, personal experience, opinion [13].

Table 5. Search string applied to *ACM.*

Repository	String	Quantity
ACM	"query": {(Title:("serious game" "serious games") OR Abstract:("serious game" "serious games" "SG")) AND ((Abstract:(concept*) AND Abstract:(model*)) OR (Fulltext:("conceptual model" "conceptual modelling")))} "filter": {ACM Pub type: Proceedings, ACM Pub type: Journals, Publication Date: (01/01/2010 TO *), ACM Content: DL}	28

Table 6. Search string applied to *IEEE Xplore.*

Repository	String	Quantity
IEEE Xplore	("Document Title":"serious game") OR ("Document Title":"serious games") OR ("Abstract":"serious game") OR ("Abstract":"serious games") OR ("Abstract":"sg")) AND (("Abstract":concept*) AND ("Abstract":model*) OR ("Full Text Only":"conceptual model") OR ("Full Text Only":"conceptual modelling") OR ("Full Text Only":"conceptual modeling")) Add filter by date: 2010 to 2021. Add filter by document: Conferences, Journals.	108

Table 7. Search string applied to *Scopus.*

Repository	String	Quantity
Scopus	(TITLE("serious games") OR TITLE("serious game") OR ABS("serious game") OR ABS("serious games") OR ABS("sg")) AND (ABS(concept*) AND ABS(model*)) OR ABS("conceptual model"*) OR ABS("conceptual modelling") OR ABS("conceptual modeling")) AND (LIMIT-TO (DOCTYPE,"cp") OR LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (PUBYEAR,2021) OR LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) OR LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013) OR LIMIT-TO (PUBYEAR,2012) OR LIMIT-TO (PUBYEAR,2011) OR LIMIT-TO (PUBYEAR,2010))	422

4. SMS Results

4.1 Answers to RQs

This section aims to answer the research questions (RQs) based on the analysis performed on the primary studies.

RQ1: What contributions does it make regarding the conceptual modeling of serious games?

Céspedes-Hernández *et al.* [PS1] published a conceptual metamodel specifically designed for the development of serious games aimed at treating hearing disabilities. It is based on class diagrams that define a context, the characteristics of the disability and its treatment. The authors relate these elements to a design model that shows the strong interaction between the role of the patient as a user of the Serious Game and the guidelines of the specialist in determining the actions to be carried out.

Bennis et al. [PS7] evaluate and compare five design models applied to serious games. As an

extension of their work, they propose the development of a tool aimed at solving the problems found in the DICE model in [PS11].

Carvalho *et al.* [EP31] present an ATMSG (*Activity Theory-based Model of Serious Games*) framework, an extension of LM-GM, through which high level requirements can be related with specific serious game design concepts. It is a specialized tool which might be useful for both developers and experts in this field. ATMSG fills existing gaps of previous frameworks, but it is more complex and has a higher learning curve.

Perrin *et al.* [PS10] show how a *Model-View-Controller* (MVC) architecture can be used to incorporate a virtual teacher to a serious game.

Hirdes *et al.* [PS24] define a set of requirements that a serious game must meet, in order to define a modeling language with a structure that supports them and which makes it possible to reuse what has been developed in other projects.

After a thorough analysis of the literature available, Alserri *et al.* [PS22] propose a conceptual model aimed at increasing women's interest in computer science subjects.

Durk-Jouke van der Zee *et al.* [PS2] propose a conceptual modeling framework for simulation serious games, which is based on a sequence of ordered and iterative steps and activities.

In turn, Bellotti *et al.* [PS8] present a framework with a conceptual model which provides a consistent development margin, from content design to deployment.

A large number of the primary studies propose methodologies relating to some specific aspect of serious games. Martin *et al.* [PS5] present the use of L-systems for scenario generation. In turn, Chaffin *et al.* [PS3], Asuncion *et al.* [PS4], Baldeón *et al.* [PS9], Zaki *et al.* [PS21], Rocha *et al.* [PS6] and Amab *et al.* [PS23] address the development process itself and its life cycle as software.

Summing up quantitatively, the majority of the contributions found fall under the "Methodology" and "Framework" categories, with 10 PSs in each of them. Then, there are four PSs proposing a "Procedure" and two PSs proposing a "Technique". In addition, only one PS proposes a "Tool" and only one PS proposes a "Language". There are six PSs whose contributions were classified as "Others". It should be noted that the sum of the indicated numbers exceeds the total number of primary studies. This is explained by the fact that some of them were classified under more than one contribution category.

RQ2: In what fields are serious games used?

Most primary studies focus on the education field, accounting for 54% of the studies. In the remaining primary studies, certain homogeneity is observed between medicine and engineering. It should be pointed out that 19% of the studies do not specify the field in which the serious games are used.

The literature reviewed also included articles with proposals of specialized frameworks for certain fields. Examples of these are the studies by Céspedes-Hernández *et al.* [PS1], Martin *et al.* [PS5], Bellotti *et al.* [PS8], Mayr *et al.* [PS13], Abdelgawad *et al.* [PS15] and Huynh *et al.* [PS27].

The number of PSs classified according to area or field is detailed below. The education category is at the top of the ranking with 17 PSs. Then, there are seven PSs which do not mention any specific field. The rest are distributed among medicine (three PSs), engineering (two PSs), military (two PSs) and Others (four PSs).

RQ3: Which is the Modeling Language used in serious game projects?

A large number of primary studies do not provide a clear answer for this question. It is observed that many of them rely on the *Unified Modeling Language* (UML) as their basis, including: Céspedes-Hernández *et al.* [PS1], Perrin *et al.* [PS10], Bennis *et al.* [PS11], Avila-Pesantez *et al.* [PS12], Nurhadi *et al.* [PS14], Hamiye *et al.* [PS17], Roungas *et al.* [PS19], and Hirdes *et al.* [PS24]. However, Nurhadi *et al.* [EP14], Hamiye *et al.* [EP17] and Zahari *et al.* [EP28] argue that the existing conceptual modeling languages have limitations in terms of supporting all the requirements of serious games and propose extensions of specific domain-based languages which include the structural and logical models required to implement the learning processes and the game dynamics within the same framework.

Nurhadi *et al.* [EP14], Hamiye *et al.* [EP17] and Zahari *et al.* [EP28] analyze the GLiSMo modeling language, which is based on UML diagrams and oriented to the development of adventure games. Nurhadi *et al.* [EP14] further analyzes ATTAC-L and Petri Nets, and their application to serious strategy games. They point out that since UML is a general-purpose modeling language, it has shortcomings that make it difficult to apply it in an environment based on *Model Driven Development* (MDD).

In turn, Hamiye *et al.* [EP17] analyze authors who use UML and *Domain Specific Language (*DSL) in the development of MDD-based serious games. They propose a mixed framework for the development of serious assessment games, which combines UML for the general structure of the game and DSL to define its logic. From these definitions, the code of the game to be developed can be generated.

Regarding GLiSMo, however, Zahari *et al.* [EP28] observe that it does not cover all the necessary requirements for the development of serious adventure games, nor does it align adequately with learning theories. To fill this gap, they propose FA-GLiSMo, an extension of the language that incorporates Flow Theory.

There are fourteen articles which do not mention the modeling language used. This is the case of Durk-Jouke van der Zee *et al.* and Bart [PS2], Chaffin *et al.* [PS3], Asuncion *et al.* [PS4], Bennis *et al.* [PS7], Bellotti *et al.* [PS8], Mayr *et al.* [PS13], Biloshchytskyi *et al.* [PS16], Mestadi *et al.* [PS18], Uskov *et al.* [PS20], Zaki *et al.* [PS21], Alserri *et al.* [PS22], Arnab *et al.* [PS23], Hall *et al.* [PS25], and Mettler *et al.* [PS29]. On the other hand, Chaffin *et al.* [PS6] propose the use of *Deterministic Finite Automaton* (DFA), *Discrete Event System Specification* (DEVS) and *Fuzzy Inference Systems* (FIS).

The study conducted by Avila-Pesantez *et al.* [PS12] mentions the UP4EG modeling language, which was used to model the case study in children with learning difficulties. In turn, the DSML modeling language is mentioned in [PS14], [PS17] and [PS28].

RQ4: What diagrams are considered for modeling in serious game projects?

While Nurhadi *et al.* [PS14], Hirdes and Leimeister [PS24], and Zahari *et al.* [PS28] use domain diagrams to represent pedagogic and constructive models of game, Céspedes-Hernández *et al.* [PS1], Perrin *et al.* [PS10], Hamiye *et al.* [PS17], and Roungas *et al.* [PS19] use class diagrams for that purpose. In addition, for the flows that define the game mechanics, Baldeón *et al.* [PS9], Nurhadi *et al.* [PS14], Hirdes *et al.* [PS24], and Zahari *et al.* [PS28] use activity diagrams or derivations from them. A special case is that of the study by Melero *et al.* [PS26], which proposes two diagrams based on the UML modeling language, but not included in such standard. However, Durk-Jouke van der Zee *et al.* [PS2], Avila-Pesantez *et al.* [PS12], Mayr *et al.* [PS13], Biloshchytskyi *et al.* [PS16], Mestadi *et al.* [PS18], Uskov *et al.* [PS20], Zaki *et al.* [PS21], Alserri *et al.* [PS22], Arnab *et al.* [PS23], Hall *et al.* [PS25] and Carvalho *et al.* [PS31] do not specify the use of modeling diagrams. In turn, Glenn *et al.* [PS5] proposes the use of a certain diagram using the grammar of L functional systems. Chaffin *et al.* [PS3], Asuncion *et al.* [PS4] and Rocha *et al.* [PS6] mention the use of Storyboards in their articles while Bennis et al. [PS11] mention the use of level diagrams.

Figure 2 shows a bar chart summarizing the types of diagrams suggested or used in the primary studies and their frequency.

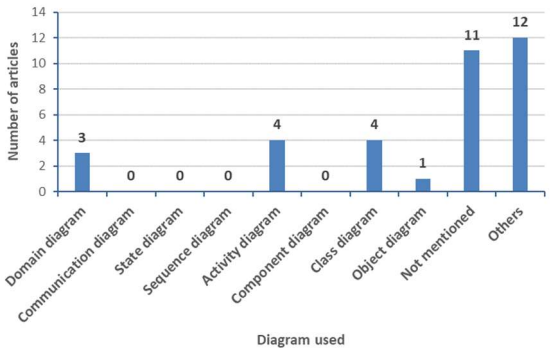

Fig. 2. Classification by Diagram used, as per RQ4.

RQ5: What are the types of research found in the articles?

We found that, of the total number of primary studies, 15 studies (48%) fall under the "solution proposal" category, mostly frameworks. There are eight articles (26%) under the "evaluation" category. The same percentage was observed for studies under the "personal experience" (4, 13%) and "validation" categories (4, 13%).

Figure 3 shows the percentage distribution for each type of research, according to Wieringa *et al.*'s classification [13].

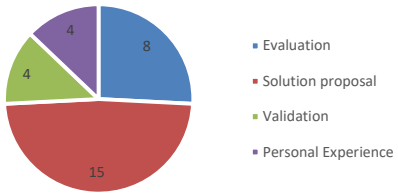

Fig. 3. Distribution of research types.

4.2. Additional Findings

In order to delve deeper into the primary studies belonging to the universe studied, some classification criteria are described, together with the results obtained.

Figure 4 below presents the number of PSs which have been published each year, within the period specified in the inclusion/exclusion criteria. As it can be observed, the year with the highest number of publications is 2015.

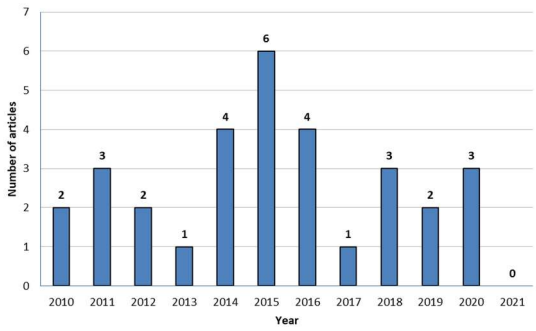

Fig. 4. Distribution of PSs according to Year of Publication.

In addition, the figure below shows the classification of primary studies according to their source (conference article or journal).

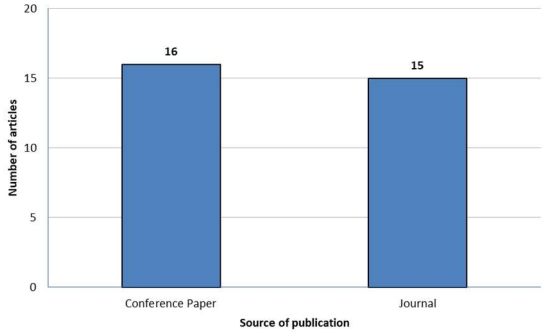

Fig. 5. Distribution of PSs according to source of publication.

5. Threats to validity

The potential threats to validity which might affect the SMS were analyzed considering the four categories suggested by Wohlin *et al.* [14].

- Construct validity. In order to mitigate this kind of threat, in this SMS we described the meaning we have attributed to the conceptual modeling and the serious games based on renowned literature [2], [3], [4], [5], [6], [7].
- Internal validity. In order to address any concerns related to internal validity, the four first authors created a review protocol as part the research from a research work conducted for the Conceptual Modeling Seminar of the Master's Degree in Information Systems Engineering (UTN-FRBA), which was reviewed by the last two authors (Seminar teachers).
- External validity. It was decided to use three search engines in our search of the journals and conference proceedings which are relevant and recommended for the Software Engineering field. Gray literature, such as articles for which only abstracts were available, PowerPoint presentations, doctoral theses or books, were excluded since the inclusion thereof might have affected the validity of our results.
- Reliability. An effort was made to mitigate the publication bias by carefully defining (a) the inclusion and exclusion criteria to select the primary studies and (b) the exclusion criteria specifically, in order to select the rules based on the research questions pre-defined in the study. To enhance reliability, a group of two students and a teacher and another group of two students and the other teacher applied the criteria separately and then classified the studies. Any discrepancy between the groups was discussed in order to determine whether a particular article should be included or not and thus the final list of primary studies was obtained. In addition, an Excel form was designed to register the data and the research questions were mapped according to the defined classification scheme to fulfil the objectives of the study. The potential effect of this bias is considered to be less important in systematic mapping studies than in systematic literature reviews. In order to enhance reliability, after applying the inclusion and exclusion criteria, a matrix with the properties of the data extracted from the article was created and they were classified according to the research questions in order to fulfil the objective of this study.

6. Conclusions and future work

This article presented a systematic mapping of the literature to analyze the state of the art in relation to the conceptual modeling of serious games. An automatic search was conducted in the *ACM, IEEE Xplore* and *Scopus* libraries in the period 2010 to June 2021. Of the 558 articles found, 31 primary studies were analyzed to answer the RQs defined in the review protocol. It is concluded that:

- Articles were found in which conceptual modeling is used as a necessary tool to guide the development of serious games. In addition, some of them stress the need for a specialist to be present in order to guide the actions to be performed by the player. This aspect is considered vital in fields such as medicine or in games assisting in the treatment of a certain disease or disability.
- According to the primary studies analyzed, the use of UML diagrams prevails in the modeling and development of serious games. However, the use of other methodologies such as UP4EG, DSML, *Deterministic Finite Automaton* (DFA), *Discrete Event System Specification* (DEVS) and *Fuzzy Inference Systems* (FIS) was also identified.

- The types of UML diagrams most frequently used in the serious game sector are class and activity diagrams.
- There were studies which, despite not using specific UML diagrams, rely on representations taken from the development of videogames, for example the use of storyboards. In turn, 32% of the primary studies do not mention the use of any specific diagram.
- It has not been possible to identify differentiating characteristics of conceptual modeling according to the field in which the serious games are used, although there were some primary studies proposing specialized frameworks for certain disciplines or problems.
- The majority of the frameworks found do not specify how to perform the conceptual modeling. Therefore, although there is much knowledge acquired about serious games, these aspects can still be further investigated.
- Thirty percent of the primary studies propose a framework for the serious game development process. The same percentage (30%) of the articles proposes a methodology.
- Forty-eight percent of the publications make a solution proposal and 26% of the studies fall under the "evaluation" category. The studies falling under the "validation" and "personal experience" categories account for 13% of the cases each. No studies were found for the "philosophical" and "personal opinion" categories.

According to what was previously mentioned, once the analysis of the primary studies was completed, the use of UML prevails as a modeling language. However, an interesting point of analysis lies in the shortcomings found in the UML for modeling serious games because, since it is a general-purpose language, it does not meet all the requirements necessary for their development, particularly in MDD-based projects. Despite this, it is observed that some authors use it to model certain elements of serious games. Such is the case of Nurhadi et al. [EP14], who take advantage of the benefits of UML to define the general structure of the serious game and DSL for its logic, thus expanding its understanding and analysis to experts from different disciplines.

Different DSML proposals have been developed in recent years to overcome the shortcomings found in the UML for modeling serious games. However, each of the analyzed DSMLs is geared towards a specific serious game genre. Therefore, it is observed that a possible line of future work, in relation to the conceptual modeling of serious games, is the elaboration of proposals for the modeling of this type of software that can be used by existing serious game design methodologies either by complementing UML or generating new specific modeling languages.

Competing interests.

The authors have declared that no competing interests exist.

Authors' contribution.

JM, ACG, NG and MB created a review protocol, and it was reviewed by MP and GV. JM, ACG and MP applied the criteria separately and then classified the studies and NG, MB and GV applied the criteria separately and then classified the studies. Any discrepancy between the groups was discussed in order to determine whether a particular article should be included or not and thus the final list of primary studies was obtained. All authors read and approved the final manuscript.

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Table 8. List of the primary studies analyzed.

Id	Primary study
[PS1]	D. Céspedes-Hernández, J. Pérez-Medina, J. González-Calleros, F. Álvarez Rodríguez, and J. Muñoz-Arteaga. "SEGA-ARM: A Metamodel for the Design of Serious Games to Support Auditory Rehabilitation," in *Proceedings of the XVI International Conference on Human Computer Interaction (Interacción '15)*. Association for Computing Machinery, New York, NY, USA, Article 10, 2015, pp. 1–8, doi: 10.1145/2829875.2829877.
[PS2]	D. van der Zee and B. Holkenborg. "Conceptual modelling for simulation-based serious gaming," in *Proceedings of the 2010 Winter Simulation Conference*, 2010, pp. 522–534, doi: 10.1109/WSC.2010.5679133.
[PS3]	A. Chaffin and T. Barnes. "Lessons from a course on serious games research and prototyping," in *Proceedings of the Fifth International Conference on the Foundations of Digital Games (FDG '10)*. Association for Computing Machinery, New York, NY, USA, 2010, pp. 32–39, doi: 10.1145/1822348.1822353.
[PS4]	H. Asuncion, D. Socha, K. Sung, S. Berfield, and W. Gregory. "Serious game development as an iterative user-centered agile software project," in *Proceedings of the 1st International Workshop on Games and Software Engineering (GAS '11)*. Association for Computing Machinery, New York, NY, USA, 2011, pp. 44–47, doi: 10.1145/1984674.1984690.
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[PS11]	L. Bennis, and S. Benhlima. "A new approach to design an attractive game based learning in various domains," in J*ournal of Theoretical and Applied Information Technology*, 85 (3), 2016, pp. 352-359.
[PS12]	D. Avila-Pesantez, R. Delgadillo, and L. Rivera. "Proposal of a Conceptual Model for Serious Games Design: A Case Study in Children With Learning Disabilities," in *IEEE Access, Vol 7*, 2019, doi: 10.1109/ACCESS.2019.2951380
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