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Review Article

Trends in game learning analysis: A systematical review of the expert literature

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ABSTRACT

This article presents a systematic review of the specialized literature using the meta-synthesis method to learn about the theoretical and empirical trends that can be found in the scientific literature on game learning analytics. The search was carried out in 17 databases and 153 results were obtained. After applying certain exclusion criteria, 17 scientific research articles were admitted for analysis. The information was classified into design, validation and implementation trends. The design findings suggest a tendency to simulate real environments with the aim of validating not only the serious game, but also the learning obtained by applying pre- and post-test measurements. A varied implementation was observed between educational purposes, training or support for people with disabilities. Likewise, pre-designed games and author's games with individual interactions were used.

Keywords: game learning analytics; design; validation; implementation; systematic review

1. Introduction

The first documented appearance of the term game learning analytics was found at the Second International Games and Learning Alliance Conference, which was held in Paris, France, in October 2013. This conference was organized by the Serious Games Society together with the Games and Learning Association and the Network of Excellence in Serious Games, funded by the European Union[1]. However, it was not until 2016 when Springer Publishing published the chapter "Game learning analytics: Learning analytics for serious games", in the book Learning, design, and technology[2].

Game learning analytics results from the union of serious game and learning analytics techniques[3,4]. Currently, it is a growing field of research involving both computational and social sciences. Its popularity has grown because internet connectivity and the use of mobile devices have increased in almost all regions of the world. In addition, educational models that incorporate this technique consider that it favors autonomous learning through playful ways[5,6].

Serious games are a set of activities conceived with explicit, specific and carefully thought out educational purposes. They are not intended for entertainment, fun or informal purposes. However, this does not mean that they cannot be entertaining[7,8].

Their design should contain clear pedagogical and educational objectives, present a simulation that clearly explains the game domain, define the progression and problems that the player will encounter, exhibit a specific aesthetic that makes it attractive to the player, explain the player's interactions with the game simulation, as well as specify the conditions of use, how, when, where and by whom the game will be used[9].

On the other hand, learning analytics seeks to develop and use methods for measuring, collecting, analyzing and communicating data, aimed at understanding and optimizing the teaching-learning process within its environment[10]. Specifically, in game learning analytics the data obtained from the player's interaction with the serious game can be used to evaluate students, predict learning outcomes, validate the serious game and find possible improvements in game design[3].

This documentary research presents the results of a systematic review applied in scientific databases to know the theoretical and empirical trends that can be found in the scientific literature about game learning analytics as an educational strategy, since its appearance, in 2015, until the current trends in its design and validation. It comprises the following sections: introduction to the topic, description of the method applied in the elaboration of the systematic review (research questions, search term, information sources, exclusion and inclusion terms, duplicate analysis and relevance analysis for literature selection) and results, which show the classifications applied in the extraction of information from the selected scientific research articles. This classification integrated serious game design trends and learning analytics, serious game validation trends and learning gained, and implementation trends that consider the characteristics of the research participants, area or learning intention, use of authored or prefabricated games, and player interaction with the individual or paired serious game. Finally, in the discussions we present the usefulness of the results, as well as lines of future research.

2. Method

The systematic review of the specialized literature was elaborated based on the meta-synthesis methodology, which integrates the results of qualitative studies and processes the data obtained inductively in order to interpret relevant findings[11]. The main objective was to understand the trends in the design, validation and implementation of game learning analytics from 2013, the year in which the first research concerning the topic is recorded, to 2020. The procedure included four stages and six steps, which are detailed in **Figure 1**[12].
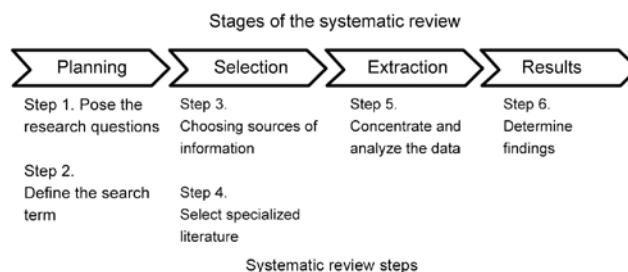

Figure 1. Stages and steps of the systematic review.

3. Planning

3.1. Pose the research questions

Our guiding research question was: what are the trends in game learning analytics design, validation and implementation from 2015 to 2020?

3.2. Define the search term

The term used in the search of the specialized literature in the scientific databases used the Boolean method. The search string entered in the scientific databases was "game learning analytics". We used quotation marks to obtain an exact match of the phrase. If quotation marks were not used, the search results showed publications that contained among their search terms the words game, learning or analytics somewhere in the text, making the results irrelevant to our objectives. We selected scientific texts that presented the exact search term ("game learning analytics") in the title, abstract or content of the specialized literature.

3.3. Selection

Sources of information

As sources of information, we selected 17 databases and included some of the main ones for education, computer science and general scientific research: Scopus, ScienceDirect, SpringerLink, Web of Science, Conricyt, Redalyc, Directory of Open Access Journals, IEEE Xplore, Dialnet, Emerald Insight, EBSCOhost, SciELO, Latindex, Association for Computing Machinery, Education Resources Information Center, Cambridge Journals Online and Oxford University Press.

Selection of specialized literature

When entering the above databases, the search query "game learning analytics" obtained 153 results, to which we applied the following exclusion and inclusion criteria, duplicate analysis and relevance analysis.

Exclusion and inclusion criteria

The characteristics for including literature in the systematic review were: scientific research articles in English and Spanish. On the other hand, to determine which scientific research articles would not be included, we considered relevance, i.e., articles that, although they met the inclusion criteria, were not relevant to the research due to their scarce information on the design, validation and implementation of game learning analytics.

For the verification and elimination of duplicates, we used the check for duplicates tool of the bibliographic reference manager Mendeley. Reviewing the title and abstract manually to ensure a thorough elimination of duplicates in the following duplicates matrix allowed us to know how many, which and in which databases the duplicate articles were found. The results achieved by applying the criteria described above are included in **Figure 2**.

Risk of bias analysis

Inspired by Sterne et al.[13], we performed a risk of bias analysis. Table 1 defines the domains and description of potential research biases: supple-
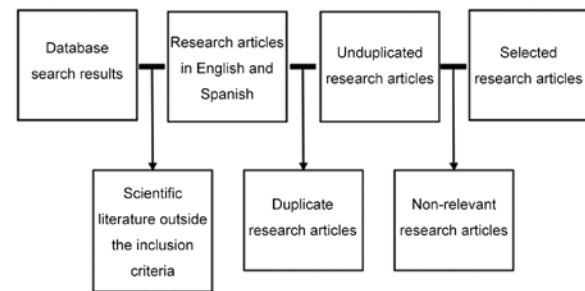

Figure 2. Process of selection of scientific literature for the systematic review.

Table 1. Description of possible bias domains

Domain	Description
Additional information	When a research article resulting from the database searches excluded because it contains additional information to that defined in the objectives of the systematic review.
Search term	When a research article resulting from searches in scientific databases is excluded for containing few mentions of the term game learning analytics
Design	When a scientific research article resulting from searches in scientific databases is excluded for not detailing coding aspects of the serious game used
Validation	When a scientific research article resulting from searches in scientific databases is excluded for not detailing algorithms implemented in the learning analytics process
Implementation	When a scientific research article resulting from searches in scientific databases is excluded for not detailing the area of implementation

mentary information, search term, design, validation, and implementation.

3.4. Extraction

Data concentration and analysis

The selected scientific research articles were downloaded and identified by integrating the name or abbreviation of the source database, an identifying number followed by a hyphen and the number of total publications found (e.g. Scopus 1–11).

The essential information of the scientific research articles was concentrated in a matrix with the following general aspects including ID, name, author(s), keywords, date of publication, doi, journal, index number, introduction, method, results, conclusions, as well as the following aspects specific to

the research question: design, validation and implementation, in addition to considerations for tools or software and other comments.

From each of the selected scientific research articles, we collected the data and categorized the results according to the research questions based on the following criteria:

- Game learning analytics design

- Validation of game learning analytics

- Implementation of game learning analytics

4. Results

The search for the term game learning analytics was carried out in 17 databases, from which we obtained 153 results. These were filtered using exclusion and inclusion criteria, duplicate analysis and relevance, resulting in a total of 17 scientific research articles. **Table 2** contains the findings by database, as well as the articles (see **Figure 3**).

The analysis of duplicates was carried out considering the databases that yielded a result for the search term entered. The databases that did not show any search results were Redalyc, SciELO, Latindex, Cambridge Journals Online, Oxford University

Table 2. Articles found and included by database

Databases	Literature found	Literature included
Scopus	28	9
Science Direct	5	2
Springer	26	1
Web of Science	11	0
Conricyt	44	1
Redalyc	0	0
DOAJ	1	1
IEEE	11	0
Dialnet	5	0
Emerald	1	0
EBSCO	7	0
SciELO	0	0
Latindex	0	0
ACM	5	3
ERIC	9	0
CJO	0	0
OUP	0	0

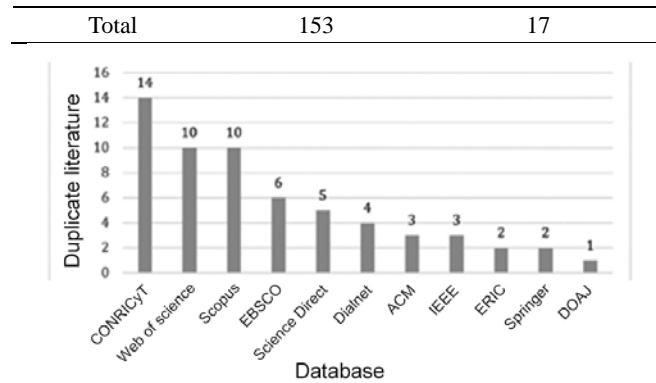| Total	153	17

Figure 3. Duplicate analysis of relevant literature.

Press and Emerald. As can be seen, the database with the highest number of duplicate articles is Conricyt.

4.1. Design trends

The findings of this systematic review indicated that there are three main categories of analysis: design, validation, and implementation; these categories contain subcategories (see **Figure 4**). The design trends of serious games used in game learning analytics focused on the development of 3D video games, simulations, puzzles, and connection games. Validation of the game learning analytics analyzed in our research was carried out using pre- and post-tests, automatic data collection, clustering and data mining. The game learning analytics were used for education, training and support of people with intellectual disabilities.
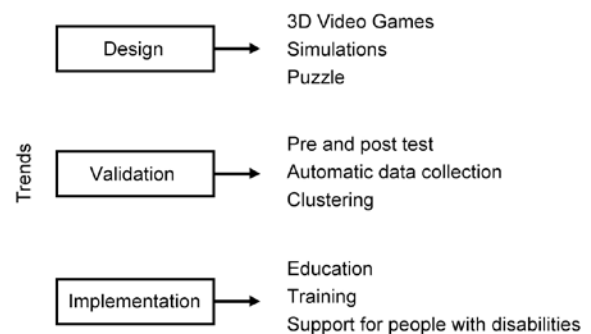

Figure 4. Study dimensions.

Every implementation of game learning analytics requires a serious game. These are not always designed specifically with learning analytics. The research analyzed showed a tendency towards 3D

video games, simulations, puzzles and connection games; all of them are prefabricated games with an external learning analytics application. **Table 3** details the author, game, type, as well as the pedagogical basis from which it was designed.

Table 3. Design of the games used in game learning analytics

Author and year	Name	Type	Pedagogical basis
Alonso-Fernandez et al., 2019.	DownTown	3D video game	Most common user characteristics and cognitive barriers
Alonso-Fernandez, 2020a	Connected	3D Puzzle	Literature concerning common bullying situations, scenarios and roles, as well as cyberbullying.
Calvo-Morata et al., 2019.	First Aid Game	Simulation	Guidelines defined by the European Resuscitation Council
Capatina et al., 2018[17]	Simbound	Simulation	Collaborative learning model
Cloude et al., 2020	Crystal Island	3D video game	Essential standards of the standard course of study for eighth grade microbiology.
Niemelä et al., 2020	GraphoLearn	Connections	Finnish language rules
Peddycord-Liu et al., 2017.	ST Math	Jigsaw puzzle	Study plan
Rotaru et al., 2018	COSMOS	3D video game	Neuropsychological tests: 15 Objects Test
Ruipérez & Kim, 2020	Shadowspect	3D video game	Study plan

4.2. Validation trends

Among the methods identified to validate the serious game and the learning obtained by the player when interacting with it, the application of pre- and post-test experiments stands out. The experiments consisted of a pre-test questionnaire, followed by the player's interaction with the serious game and, finally, the application of the initial questionnaire again (post-test). The questionnaires were pre-validated. In case a validation instrument for the questionnaire was lacking, it was developed ad-hoc[4,14–18].

The application of pre- and post-tests is a resource-consuming activity, since they are generally applied in an environment external to the serious game and require the capture and processing of data with external tools, which leads to the need to integrate pre- and post-tests into the serious game environment or to seek alternatives for their optimization[14].

Another method identified to validate learning consisted of collecting player interaction data with the serious game using the game analytics tracking technique, commonly used in commercial games for profitability purposes, although it can be adapted to educational purposes. The information obtained from the interaction data was used both to evaluate and improve the game and to track student progress and even evaluate it[4,19].

In certain situations, the collection of interaction data proved to be indispensable when the learning obtained from the player's interaction with the serious game could not be measured with pre- and post-test[3]. While the use of pre- and post-test is an effective tool for data collection, the application of xAPI-SG represents an alternative way to collect data, as it draws on high-level aggregate statistics on player and team performance[3,14,20–22].

Among the variety of alternatives available to validate learning, we found the clustering method, usually used in learning analytics. This consisted of hierarchical clustering to classify students, their learning, progress in the game and the players' learning process. A tree-like structure was used and was not advised for large data sets, as it yielded arbitrary figures. On the other hand, the K-means data mining method was applied, in which each observation belongs to a group according to the nearest mean and presents grouping in a layer with geometrically closed subsets of easy interpretation[10].

In addition to the aforementioned methods, it was possible to validate the learning resulting from the player's interaction with the serious game by applying multiple-choice questionnaires designed to measure the expected learning, in which, upon obtaining the answer, additional videos with the correct procedures were shown[3].

Data mining was also employed to validate the learning obtained by the player at the end of the interaction with the serious game: classification models, such as decision trees, logistic regression and Naïve Bayes classifier to determine pass-fail, and linear models, such as regression trees, linear

regression and support vector regression with non-linear kernels to know the exact score[3,20].

4.3. Implementation trends

Implementation trends for game learning analytics were concentrated in this category. **Table 4** shows the author, year of the research, a brief description of the participants, the purpose and time of implementation. During the implementation of game learning analytics, we used serious game, whose design was not specifically focused on the documented research, i.e., we used prefabricated serious game[4,10,14,23].

Table 4. Implementation of game learning analytics

Year and author	Study participant	Purpose of implementation	Implementation time
Alonso-Fernandez et al., 2019	Adults between 18 and 45 years of age with intellectual disabilities	Orientation in the use of the public transportation system	3 hours
Alonso-Fernandez, 2020a	K-12 students (elementary and middle school equivalent)	Increasing bullying awareness	55 minutes
Calvo-Morata et al., 2019	Students between 12 and 17 years	Instruction in cardiopulmonary resuscitation maneuvers	30 minutes
Capatina et al., 2018	Employees	Improve collaborative skills	Not specified
Cloude et al., 2020	University students	Improve the transfer and retention of scientific reasoning skills	90 minutes
Niemelä et al., 2020	Students from 6 to 9 years old	Training connections between speech sounds and letters	10 minutes
Peddycord-Liu et al., 2017	Third grade students	Support the teaching of the mathematics curriculum	60 minutes
Rotaru et al., 2018	Cognitively healthy adults over 60 years of age	Computerized neuropsychological tests	25 minutes
Ruipérez and Kim, 2020	First year high school students	Develop geometric, dimensional and spatial reasoning skills	75 minutes

In addition to empirical applications of game learning analytics, the development of a framework for designing game learning analytics for people with disabilities was reported from a theoretical approach focused on fostering serious game development in an inclusive learning environment designed with prudence, adaptive and measurable competencies to meet the needs of players[24].

Regarding students' interaction with the game, this happened individually[3,4,10,14,15,18,25,26] or collaboratively. The results are different, not necessarily superior to each other; while individual interaction allowed for greater progress in game performance and participation, binned interaction demonstrated

greater exploration of the game[23].

As a result of the analysis of the scientific research articles selected for the systematic review, we developed **Figure 5**, in which we establish the mechanics and the process to be followed in the development of game learning analytics.

5. Discussion and conclusions

This systematic review of the specialized literature with the meta-synthesis method had the objective of knowing the current theoretical and empirical trends in the scientific literature about game learning analytics. It highlighted the fact that the preponder-

ant design was 3D video games and simulations. This coincides with the specialized literature regarding a clear incorporation of immersive digital
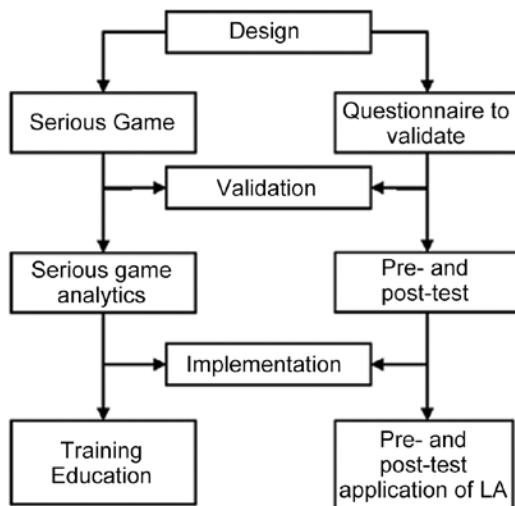

Figure 5. Trends in design, validation and implementation of game learning analytics.

technology in learning processes, and whose most sophisticated stage is the recently popular Metaverse[27–29]. However, when reviewing the year of publication of that literature, it was evident that the immersive trend, at least in education, already dates to about a decade, which can be interpreted as a trend that is hardly novel, but unfinished.

Regarding the validation of game learning analytics, it was evident that there is a marked tendency to use quantitative procedures and instruments. This coincides with the proposals of big data analysis, but is contrary to the educational discourse focused on learning. In other words, in validation, the emphasis has been on the optimization of the artifact, but not on knowing in breadth and depth what problems students have when experiencing a game learning analytics and how they solve those problems. It is necessary to introduce proposals for artifact validation with a qualitative approach, as well as to initiate qualitative studies on learning with this type of models[30,31].

The third finding lies in the areas in which these prototypes have been implemented. It is striking that the areas of formal and non-formal education are equally addressed. This is symptomatic of a shift of interest towards alternative learning methods, not only of prototypes, but of educational contexts. The three findings above, in general, coincide with the trends that the specialized literature in educational technology is developing: new educational models and prototypes applied in formal, non-formal and informal contexts. However, a relevant suggestion is for more qualitative studies[32,33].

In conclusion, in this paper we explain the trends in design, validation and implementation of game learning analytics. The research area for this term is recent and growing. Scientific research articles that comprehensively develop the topic are scarce and are considerably duplicated in databases.

Understanding the trends of design, validation and implementation of game learning analytics favors the consolidation of the term, and serves as a guide not only for researchers in educational areas, but also for developers or researchers interested in elaborating this type of resources. It is important to highlight that the design trends for this learning analytics are inclined to the selection and implementation of a serious game rather than to its development, which facilitates and makes available the use of game learning analytics for educational purposes for teachers who have little technological training in the development of serious game and learning analytics.

Finding few authors and scientific research articles hindered the elaboration of the systematic review. However, it opens the door to future work, especially regarding the pedagogical basis on which game learning analytics will be developed. Although some researches base the implementation and validation on standards, idiomatic norms and diverse literature, none of them mentions the application of an educational model as such. We can conclude that the research documented and analyzed in this systematic review leans towards an empirical application. Undoubtedly, there is a need to expand both the research and its publication.

Conflict of interest

The authors declare no conflict of interest.

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