The Use of Learning Analytics Interactive Dashboards in Serious Games: A Review of the Literature

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Abstract

The learning analytics in serious games, corresponds to a subject in increasing demand in the educational field. In this context, there is a need to study how data visualizations found in the literature are adopted in learning analytics in serious games. This paper presents a Systematic Literature Review (SLR) on how the evolution of studies associated with the use of learning analytics interactive dashboards in serious games is processed, seeking to investigate the characteristics of using dashboards for viewing educational data. A bibliometric analysis was carried out in which 75 relevant studies were selected from the Scopus, Web of Science, and IEEExplore databases. From the data analysis, it was observed that in the current literature there is a reduced number of studies containing the main actors in the learning process, as follows: teachers/instructors, students/participants, game developers/designers, and managers/researchers. In the vast majority of investigated studies, data visualization algorithms are used, where the main focus takes into account only actors, such as teachers/instructors and students/participants.

Keywords: Learning analytics; serious games; data visualization; interactive dashboards

1. Introduction

With the breakthrough in digital technologies, the educational field has been seeking to update itself with regard to active teaching methodologies such as serious games (Chaudy & Connolly, 2019). Serious games prove to be very effective in the teaching-learning process and in retaining users, in addition to providing a wide variety of possibilities that can be difficult to obtain in a traditional classroom (Chaudy & Connolly, 2019).

Serious games make the learning process more fun, challenging and rewarding, making it possible for the user to be involved in the game and not notice that they are immersed in a teaching-learning system (Ali, Shatabda, & Ahmed, 2018). In addition, serious games allow users to adopt their own pace of study (Chaudy & Connolly, 2019). However, high performance in a serious game does not necessarily imply effective learning. In a game, satisfactory performance is related to reaching a milestone and obtaining a high score, whereas learning refers to reflection, repetition and self-assessment of the mistakes made

(Massa & Kuhn, 2019).

In that context, the evaluation of the user within a serious game is fundamental to the teaching-learning process. The most common method for evaluating serious games is by performing a test before and after the user participates in the game, and from the results obtained, perform a statistical comparison (Alonso-Fernandez *et al*., 2017). That pre- and post-test method is expensive, time-consuming and provides limited information about the user in the learning process (Alonso-Fernandez *et al*., 2017). For those reasons, learning analytics has seen a more effective method of teaching-learning assessment. Learning analytics can be used as part of an evaluation approach, in order to verify whether games are achieving good learning results, providing data on user interaction with the game in real time (Callaghan *et al*., 2018).

Learning analytics refers to the collection, analysis and visualization of a large amount of data related to educational processes (Slimani *et al*., 2018), thus determining which information needs to be extracted from a serious game for the analysis process (Callaghan *et al*., 2018). The extraction of that data can occur through web logs, tracking mechanisms, eyepieces, location and movement detectors (Massa & Kuhn, 2019). After extraction, those data must be processed through data mining and, finally, information visualization techniques must be used to assist in the interpretation of the data and identification of possible patterns.

The data visualization is a fundamental characteristic within a serious game, as it is through the representation of the data that the educational efficiency is verified, providing means to evaluate the knowledge obtained by the user (Alonso-Fernandez *et al*., 2017).

Normally, the data visualization is done through a dashboard. The visualization must occur in a significant way, so that the dashboard is not overloaded with information and only has information that has a certain purpose, aiming at a satisfactory user experience (I. J. Perez-Colado *et al*., 2018a). Dashboard views are characterized by presenting the activities performed by users over time (Martínez-Ortiz, *et al*., 2019).

In that context, the following research question is elaborated: how is the evolution of studies associated with the use of learning analytics interactive dashboards in serious games processed? To answer that research question, it is defined the main goal of the Systematic Literature Review (SRL), to understand the evolution of studies related to the use of learning analytics interactive dashboards in serious games, scientific productions in different areas of knowledge, evaluation metrics adopted, and the identification of possible gaps and opportunities for future research on the topic.

In order to achieve that goal, the work is structured as follows. The next two Sections explore the subjects “Learning Analytics” and “Learning Analytics in Serious Games” by different authors. Soon after, the methodological procedures are presented. In order to assist in the understanding of the object of study, this work presents the results of an SRL in electronic databases on the associated variables, identified in theoretical and empirical studies. Finally, the paper discusses the theoretical and practical implications of the results.

2. Learning Analytics

Learning analytics is a data analysis method, designed to assist in the understanding of students' tendencies towards activities and the significant aspects of those activities in their teaching-learning process (Kim & Moon, 2018), making it possible to identify students at risk of failure and learning difficulties.

In order to reduce the risk of failure and the difficulty of students in certain areas of teaching, games were seen as a powerful tool for learning and for evaluating (Chaudy & Connolly, 2018), since games provide an interactive and fun environment. At the same time, through the collection of educational data, it is possible to obtain relevant information on user game interaction (Slimani *et al*., 2018). Another aspect of great relevance is the evaluation, which, part of it can be carried out through learning analytics, to evaluate if the games are achieving satisfactory learning results and to provide information in real time about possible game deficiencies (Hauge, Berta, *et al*., 2014).

The information obtained through learning analytics corresponds not only to a report, but also to the descriptions of potentials, standards, and validation actions of statistical significance. In that way, it is possible to understand the dynamic performance of users, risk patterns in the teaching process and work factors to be adjusted in the search for improvements in the learning process (Massa & Kuhn, 2019). Because of those benefits, learning analytics is not only used in the educational field for game analysis, but also in organizations such as business analysis, web analysis, social network analysis and academic analysis (Massa & Kuhn, 2019).

3. Learning Analytics in Serious Games

In the serious game the main objective is to use digital game technology in teaching and learning and not necessarily in entertainment (Chaudy *et al*. 2014).

Serious game is effective in increasing interest in learning and allowing training and evaluation of user performance (Slimani *et al*., 2018). A priori, all serious games are part of an evaluation mechanism, in order to verify the player's performance and progress, thus generating a large set of data that allow the monitoring of user actions (Hauge, Berta, *et al*., 2014).

That data can be collected in two ways: the first is through pre- and post-test, in order to check the users' previous knowledge and compare with the knowledge acquired after the contact with the serious game (Massa & Kuhn, 2019) ; the second refers to the collection of information performed during the game, which can occur through web logs, tracking mechanisms, sensors such as eye trackers, location tracking, and motion detectors. In addition, the combination of serious games with learning analytics results in improvements in the monitoring and evaluation of game-based learning (Hauge, Berta, *et al*., 2014). In general, the data collected provides insights into the learning experience, the learnings related to the virtual environment, as well as the actual performance during the game (Hauge, Berta, *et al*., 2014).

In the context of serious games, learning analytics is an area of emerging knowledge that provides detailed reports on the use of a game; gameplay data and information visualization, based on data mining processes (Chaudy & Connolly, 2019). The combination of learning analytics techniques and serious games results in learning analytics in serious games (Serrano-Laguna *et al*., 2014).

According to Petrov *et al*. (2019), interactions between serious games and learning analytics occur for two main reasons: learning analytics used with the aim of improving a serious game; and, using serious games

to improve the quality of learning analysis. One of the goals of learning analytics is to improve learning through the processing and visualization of educational data (Cariaga & Feria, 2016). This visualization usually occurs through dashboards with tables or graphic forms (Cariaga & Feria, 2016). Ideally, the data sets obtained through the learning analytics should be viewed through interactive and adaptive dashboards, varying according to the needs of the game's users (Alonso-Fernandez *et al*., 2017). Those data sets can generate information for several purposes, such as: student assessment; personalized and adaptable gameplays and improvement in the serious game (I. J. Perez-Colado *et al*., 2018b). Therefore, learning analytics must be an interactive and adaptive process for the various parties involved, such as: teachers/instructors, students/participants, game developers/designers, and managers/researchers (Alonso-Fernandez *et al.,* 2017).

4. Methods

In this study, the Systematic Literature Review (SLR) was adopted and as a methodological procedure, a bibliometric analysis with a quantitative basis was carried out, in order to fulfill the research objectives. Freire (2013), mentions that the SLR procedure must be exploratory, in order to search and analyze publications already made on the subject. The author describes seven steps to be followed to search and analyze a SLR according to the Cochrane Handbook and NHS/York manual, they are: question formulation; location and selection in databases; critical evaluation of studies; data collection; analysis and presentation of data; data interpretation; and improving and updating the review.

4.1 Search Strategies

In the planning stage, the research question was defined, as well as the databases used to research the state of the art and the inclusion and exclusion criteria for articles for SRL. For this study, the international databases SCOPUS Elsevier, Web of Science, and IEEExplore were selected. The search descriptors used in the databases were "learning analytics" AND "serious games". In this research, the terms searched in English and Portuguese were taken into account. Table 1 shows the search variables used in the databases and the number of articles resulting from the search.

Table 1 - Search descriptors used in the databases

Databases	Search Descriptors	Articles
SCOPUS Elsevier	(TITLE-ABS-KEY ("learning analytics")) AND ("serious games") AND (LIMIT-TO (DOCTYPE, "ar"))	65
Web of Science	webscience: TS = (("learning analytics") AND ("serious games")) Refined by: DOCUMENT TYPES: (ARTICLE)	17
IEEExplore	("learning analytics") AND ("serious games")	33

The inclusion and exclusion criteria for articles are shown in Table 2.

Table 2 – Inclusion and exclusion criteria

Inclusion Criteria	• Article related to learning analytics, after reading the abstract
	• Article related to serious games, after reading the abstract
Exclusion Criteria	• Duplicate article
	• Unavailable article
	• Incomplete article
	• Article not related to learning analytics, after reading the abstract

4.2 Selection of Studies and Methodology Quality

In order to assist the process of inclusion and exclusion of articles, the Start tool (State of the Art through Systematic Review) was adopted for the export of articles, as well as for the analysis and selection of studies (Lapes, 2017). After reading the abstracts of the 115 articles, the selection criteria for the inclusion of articles were performed, described in Table 2. In that stage, 104 articles were accepted and 11 were rejected articles.

Then, the extraction step was performed, using the article exclusion criteria. At this stage, it was identified which articles were duplicated, incomplete or unavailable. Subsequently, we sought to identify the following information from the articles: Classification of the type of study, general characteristics of the study, data visualization techniques adopted and main results achieved. In that stage, a total of 75 accepted articles were obtained, 18 rejected and 11 articles were identified as duplicates.

For the systematic review of the literature, a bibliometric analysis was adopted, which is a research method and data analysis that allows measuring and evaluating results of bibliographic research on a research question (Freire, 2013). That method is used in this study in order to detect patterns of writing, publications and literature. In addition, an attempt is made to analyze the size, growth and bibliographic distributions in the field of knowledge researched (Freire, 2013). Finally, a descriptive analysis is performed to identify the results of the groupings of the analyzed data (Freire, 2013).

5. Results

For the SLR, a bibliometric analysis was performed in order to analyze the bibliographic data found in the literature and verify the evolution of studies associated with the use of learning analytics interative dashboards in serious games.

5.1 Study Classification

Studies related to learning analytics in serious games can be classified into five main types: studies with an emphasis on educational technologies; proposals for evaluation methodologies; studies with an emphasis on computational technologies; literature review studies on learning analytics; and, studies with an

emphasis on data visualization.

This Section presents the characteristics of the main articles for each type of study, in order to contextualize the main topics covered.

5.1.1 Studies with an Emphasis on Educational Technologies

Regarding studies with an emphasis on educational technologies, serious games in the area of inclusive education and socio-educational problems such as bullying and cyberbullying stand out.

In inclusive education, serious games can be used as training for activities considered common for a person without special needs. Cano *et al*. (2018), analyzes the process of creating and developing a serious game designed to train people with intellectual disabilities when traveling around the city on subway trips. The tests of serious game were carried out through the experience of adults with mild intellectual diseases (Cano *et al*., 2018). In order to analyze the needs of users with intellectual disabilities, an investigation was carried out on cognitive, psychological and motor skills, which were later translated into user requirements. Those requirements have game mechanics adapted to improve understanding and increase the probability of the user to perform the tasks correctly within the game (Cano*, et al*., 2018).

In order to analyze the effectiveness of the serious game of subway travel for people with disabilities, a learning analytics module was added, where relevant information was collected on how users are playing, allowing to infer how the learning process of each user is occurring. For that purpose, educational data are collected using analytical learning techniques during game sessions. And, to view the game results, existing standards were used in the Experience API library (xAPI) (Cano *et al*., 2018), which allows the generation of virtual dashboards with information on the students' general performance (Calvo-Morata *et al*., 2018).

A serious game that is concerned with cyberbullying is the game entitled Connected. The game puts users in the role of a student who is cyberbullyed by schoolmates. The game follows the classic adventure style, where it structures the main means of interaction in dialog options, allowing the game's story to be changed in a dynamic way resulting in possible different forms of completion (Calvo-Morata *et al*., 2018).

From the point of view of the teachers who tested the Connected game, it is important that the educational tools are under control, so that they are aware of the current situation in the classroom. In that way, it is possible for professionals to visualize the student's progress and assess whether the tools are serving their purpose. In that case, it is necessary to perform data collection and analysis (Calvo-Morata *et al*., 2018).

5.1.2 Proposals for Evaluation Methodologies

Within the context of learning analytics in serious games, it is possible to notice a great concern regarding the use of an appropriate evaluation methodology. Regarding evaluations in serious games, it is necessary to verify patterns of behavior in the data records, in order to identify and measure the implicit learning and the development of knowledge that has not yet been identified.

To record the data Rowe *et al*. (2017) made use of the tool called Impulse, which records game events, as well as the location of objects in the game space and the feeding of that information into the database. To that end, five main categories were defined: (a) location/vector and movement of player particles; (b) moment and location of the impulses; (c) number and location of other particles; (d) general characteristics of the game; and (e) result of the game.

The authors (Rowe *et al*., 2017) applied the techniques mentioned in two serious games for teaching physics. The study resulted in several measures of implicit learning and significant improvements in external assessments.

Gibson & de Freitas (2016), described how evaluation data can be used to fully understand the student experience. According to the authors, one way to obtain data is during the game session, where the individual's experience can be modeled and mapped in an effective way providing feedback throughout the game experience.

Another relevant factor regarding the student's experience is the user's retention throughout their gaming experience. Taking that factor into account, it is possible to visualize the benefits of using performance data throughout the game's life cycle. Thus, the data in question can be used in the planning and implementation of interventions during the user study (Gibson & de Freitas, 2016), making the level of difficulty to be adapted for each type of user, thus creating a better type of assessment for each student profile.

Assessment is essential for students to receive feedback on their progress, and for educators to assess the effectiveness of their teaching. However, educators do not always trust the result of serious play. In order to address that problem Chaudy *et al*. (2014) developed a general evaluation mechanism used as a link between developers and educators, entitled EngAGe. At EngAGe, the teacher/instructor creates the assessment by providing guidelines and allows the assessment to be updated at any time after the game is distributed. The evaluation step is carried out in an independent module, which does not require a programming language. The system proposed by the authors presents a panel that provides a visual report summarizing all the data collected from the various phases of the games (Chaudy *et al*., 2014).

5.1.3 Studies with an Emphasis on Computational Technologies

Computational technologies aim to bring innovative tools that assist in the construction of serious games and in the collection, standardization and analysis of educational data. In that context, the Experience API library (xAPI) stands out. The xAPI library is an interaction model to track user data, in order to carry out learning analysis in serious games (Serrano-Laguna *et al*., 2017).

The xAPI library defines each event tracked in a learning activity as a "statement". The main attributes in an instruction are actors, verbs (action) and objects. The xAPI instructions are sent to a database so that it is possible to check sequences of interactions performed by users. Finally, the data are presented on dashboards for students and educators (Serrano-Laguna *et al*., 2017).

The collection and analysis of data proves to be an extremely relevant tool among computational technologies, presenting behaviors of great significance for the learning process. In the study carried out in the Learning Management System, a learning platform was developed to collect data not only on the use of the system, but also related to the way students learn and progress training activities (Villagrá-Arnedo *et al*., 2016). In order to verify the hypothesis that complementing behavioral data with other more relevant data (related to the learning results) can lead to a better analysis of the learning process, making it possible to predict the student's final performance in advance. The study showed satisfactory results and classified users with the probability of belonging to one of the three classes: high, medium and low performance (Villagrá-Arnedo *et al*., 2016).

Studies in computational technologies also stand out, for addressing the development and application of

assessment tools in serious games, such as the EngAGe tool, which is an integrated assessment tool for teachers and developers designed to separate the serious game from the system evaluation (Chaudy & Connolly, 2019). Developers use the tool to integrate assessment with teaching using games. In addition, teachers have the possibility to modify the assessment and view the learning analysis through a data control dashboard (Chaudy & Connolly, 2019).

In order to test EngAGe, a qualitative assessment was carried out with the developers, where 7 experienced developers and 29 students were selected (Chaudy & Connolly, 2019). Qualitative evaluation was also carried out by 31 educators, and it was observed that with access to EngAGe, it is more likely that educators trust the evaluation of the game, since EngAGe can be used by educators effectively to modify educational games, evaluate, and view gameplay data (Chaudy & Connolly, 2018). According to the authors, in that way EngAGe allows an increase in confidence in educational games as an assessment tool (Chaudy & Connolly, 2018).

5.1.4 Literature Review Studies on Learning Analytics

In the classification of studies of literature review, what stands out most are the works that present a relationship between serious games and learning analytics.

Massa & Kühn (2018) present the following research questions in their study: (a) what kind of solutions are perceived in studies on learning analytics in serious games?; (b) are there studies on learning analytics for commercial serious games that have not been developed by educators?; (c) were studies published that offer analytical methodologies for implementing learning in serious games?; and (d) are there studies that offer tools for implementing learning analytics in serious games?

As results of the study, the authors obtained the following answers: (a) there are two main lines of research, those that offer theoretical solutions on the subject, and those that already offer practical solutions, already implemented or in the process of future implementation. The authors noted that 33% of publications maintained a theoretical approach, while the other 67% proposed a more practical than theoretical focus; (b) only one article found has partly commercial applications; (c) the authors identified some proposed methodologies for the implementation of learning analytics; (d) the authors found few complete software that allow the incorporation of learning analytics in a serious game, in addition, the articles that were found focus directly on the student's assessment within the serious game (Massa & Kuhn, 2019).

5.1.5 Studies with an Emphasis on Data Visualization

In the vast majority of the investigated studies, the data visualization in relation to learning analytics, showed a greater focus on information associated with users/students and instructors/teachers, being used mainly to assist in the analysis of learning.

In the view of Alonso-Fernandez *et al*. (2017) in the analysis and visualization stages, there are two main objectives to be achieved: (a) standards of analysis and visualization sets should provide insights, thus making it possible to personalize with zero cost; and (b) advanced users must be allowed to add specific information by creating custom dashboards and views.

In addition, the sets of analysis and visualization standards must be adapted to the needs and interests of the different stakeholders involved in the learning process, namely: teachers/instructors,

students/participants, developers/ designers, managers/researchers (Alonso -Fernandez *et al*., 2017).

For teachers, the main characteristics related to data visualizations are: user classification by number of errors, questions with a higher error rate; number of players in each game session; total number of correct and incorrect alternatives selected in the multiple choice questions for each player; score and progress achieved by players at different levels; players' progress over time; and for each activity, rule, game suggestions, the number of times that were visited and ignored by the players (Alonso-Fernandez *et al*., 2017).

According to the authors, it is interesting for students to view answered questions, errors, proportion of correct answers, final score, timestamps, and session duration (Alonso-Fernandez *et al*., 2017).

For developers or designers, views with the following characteristics are considered relevant: views by students in the class, sessions, questions answered, total errors, proportion of correct answers and timestamps; distribution and questions answered of the scores obtained in the game; number of accesses performed by the players; duration of sessions; number of times that each verb has been used over time (Alonso-Fernandez *et al*., 2017).

And, for managers and researchers, relevant visualizations (Alonso-Fernandez *et al*., 2017) must contain: peak times of game use and intergroup comparisons.

Alonso-Fernandez *et al*. (2017) developed the visualization dashboards with a tool called Kibana, as it is a platform that provides flexible navigation with an interface based on analysis and visualizations. Once created, those dashboards can dynamically change to display updated results as they become available.

Melero *et al*. (2015) explores visualizations to support student self-assessment and teacher assessment. The proposed design is a gamification composed of a location-based learning activity, containing geolocated questions.

The “QuesTInSitu: The Game” proposed by Melero *et al*. (2015) provides the data for the visualizations, which represent relevant aspects of the group activity. According to the authors, the interactions occurred by 23 groups of students with the application in their mobile design, including data such as: time used to answer questions and to reach the geographical area of the questions, number of attempts to solve each question and scores obtained per question. With that information, several visualizations of learning analysis were possible for the evaluation of teachers and self-evaluation of students (Melero *et al*., 2015). The assessment was divided into sessions, which are: general information, time used, trails, frequency, and score (Melero *et al*., 2015). For teachers, they are important information to maintain the objectivity of the application, however, they can present a large volume of information to be analyzed (Melero *et al.,* 2015).

Another approach is the visualization through dashboards oriented to the teacher, where there is an administrator dashboard containing an interactive menu that allows the user to select the desired dashboard, while the students' performance information is displayed in a main table (I.J. Perez-Colado *et al*., 2018). According to the authors, the type of visualization adopted can also be filtered or not by student. Those dashboards are composed of five sections that are presented in the form of bar graphs, slices and region, they are: general information and configuration; scores; responses; progress and duration; and location-based games (I. J. Perez-Colado *et al*., 2018).

5.2 Analysis of Studies

In the bibliometric analysis, important aspects related to the 75 selected studies referring to "learning analytics" and "serious games" were considered (Appendix A). In this analysis, mappings were made relating the classification of the type of study, publications per year, techniques adopted, as well as the use of interactive dashboards.

Regarding the classification of types of study, as noted in Appendix A, a classification was made according to the type of approach of each article, within the context of learning analytics and serious games. As shown in Figure 1, it was observed that the largest number of the articles are related to studies with an emphasis on educational technologies (36%) and computational technologies (31%). These results reflect the growing number of studies in the development and application of serious games, in order to create innovative tools that are effective during the learning and evaluation process.

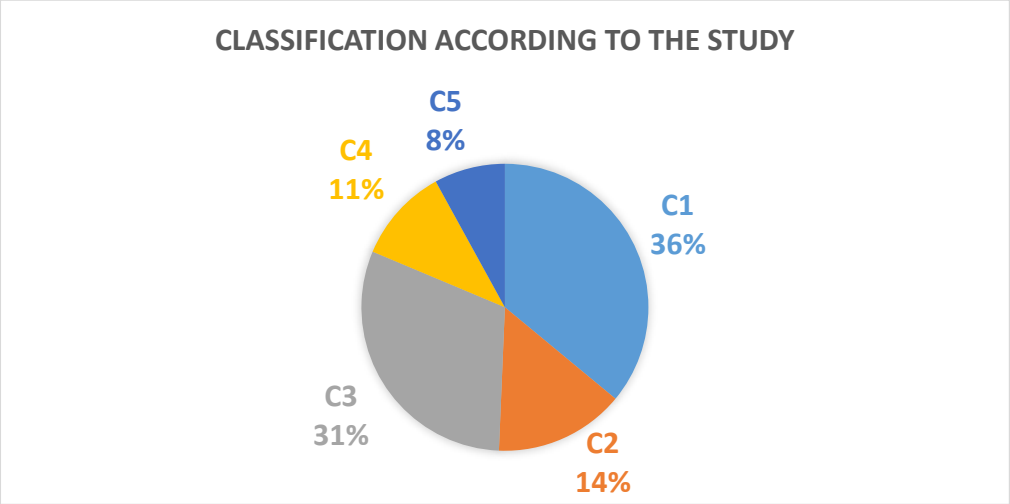

Figure 1 – Studies classification.

C1: Studies with an emphasis on educational technologies; C2: Proposals for evaluation methodologies; C3: Studies with an emphasis on computational technologies; C4: Literature review studies; C5: Studies with an emphasis on data visualization.

Regarding the number of publications, Figure 2 shows the evolution of studies on learning analytics in serious games between the years 2014 to 2019. It is notable the significant increase in publications on the subject from the year 2016, having just a small drop in 2015 and doubling the number of publications from 9 in 2017, to 18 publications in 2018 and reaching 24 publications in 2019.

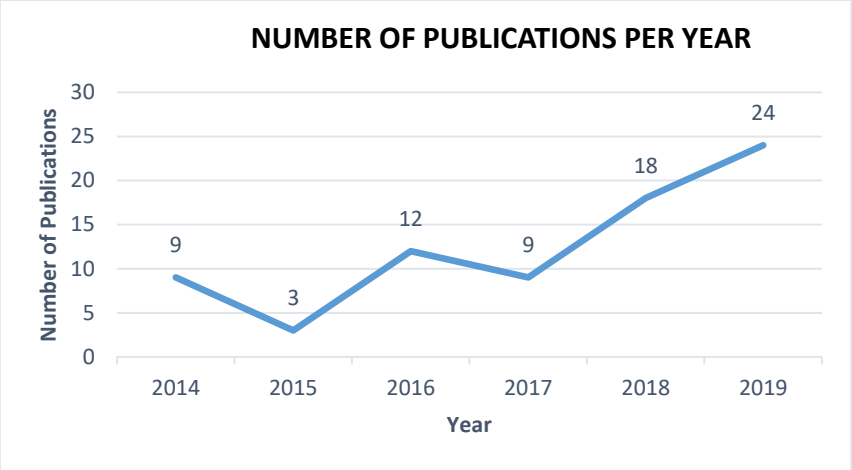

Figure 2 – Evolution in the number of publications.

Another important information is the number of citations per article (Appendix A). In this context, on of the highlights is the study by Serrano-Laguna *et al*. (2014) which proposed a two-step approach for the application of learning analytics, where in the first step occurs the identification of generic features and, the second step, the definition of reports that can be applied in any type of game. In addition, Serrano-Laguna *et al*. (2017), which presents game-specific evaluation rules based on combinations of generic tracking. In that particular study, a new interaction model is presented to track learning in serious games and their implementation using the Experience API library (xAPI) (Serrano-Laguna *et al*., 2017).

In this context, it is possible to notice a great relevance and concern of the work of learning analytics in serious games in tracking educational data, in order to create reports. The way of viewing those data reports is also of great relevance for users, teachers/instructors and researchers. In Figure 3, it is observed that 65.3% of the investigated articles (n = 75), do not apply any data visualization technique (N/A) and only 10.7% of the articles use interactive and adaptive dashboards (V3), 2.7% present the data through hierarchical maps (V2) and 21.3% present the data reports through static dashboards (V1), for individual results and/or groups of users.

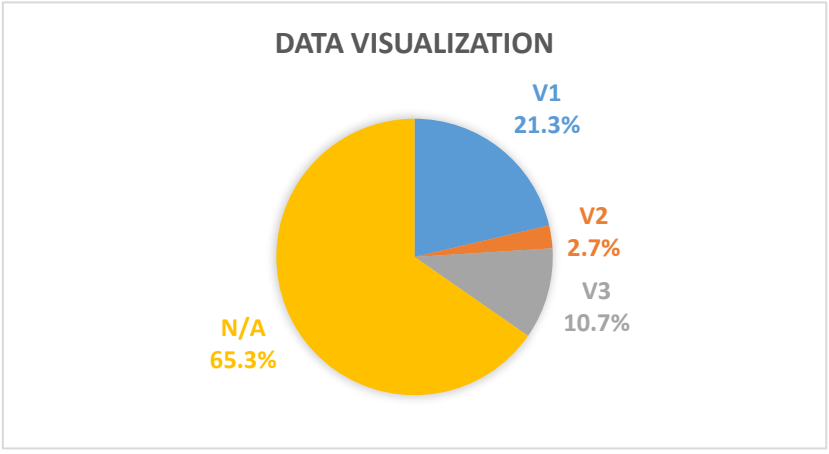

Figure 3 - Data visualization techniques adopted.

V1: Visualization through static dashboards with individual results and/or group of users; V2: Visualization through hierarchical maps; V3: Visualization through interactive dashboards with individual results and/or group of users; N/A: Not applicable.

In order to keep track of the progress and actions of users, data visualization is relevant for educators and students. Visual analyzes that aggregate the learning analysis data during the game session, based on control dashboards allow an overview of the participating student groups (Calvo-Morata *et al*., 2019).
The use of an interactive dashboard, which allows to obtain filtering by student, chosen paths, progress, actions in the game, answers, scores, times for completion, among others, is of great relevance, so that educators can also view detailed information on learning during a session of a serious game (Calvo-Morata *et al.,* 2019). It can be observed (Figure 4) the evolution in the studies of learning analytics interactive dashboards in serious games in 2016 and a significant growth until 2019. Figure 4 shows that the visualizations through static dashboards, also remain in increasing, despite a drop in its use between the years 2015 and 2016.

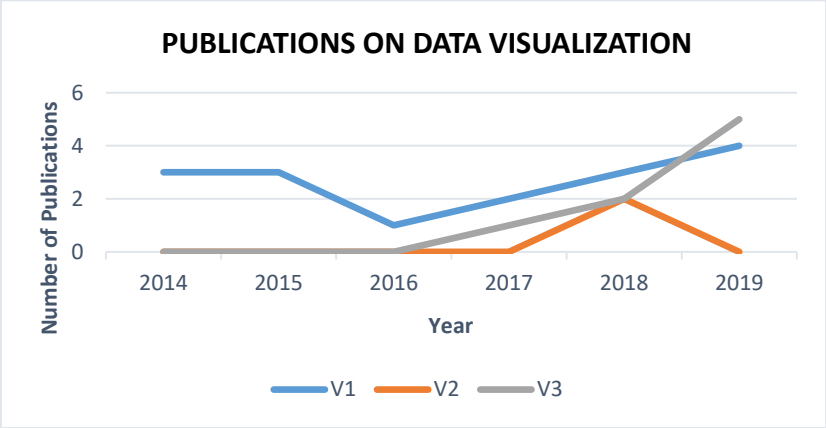

Figure 4 – Publications on data visualization.
V1: Visualization through static dashboards with individual results and/or group of users; V2: Visualization through hierarchical maps; V3: Visualization through interactive dashboards with individual results and/or group of users.

In particular, studies with an emphasis on data visualization (category C5 in Appendix A), articles that are concerned with visualization by the teacher/instructors and the student/participant stand out, as shown in Figure 5. It was found only one article that presents the visualization for all the actors participating in the learning process, namely: teachers/instructors, students/participants, game developers/designers and managers/researchers. And, two studies that present the visualization aimed only at the teacher/instructor.

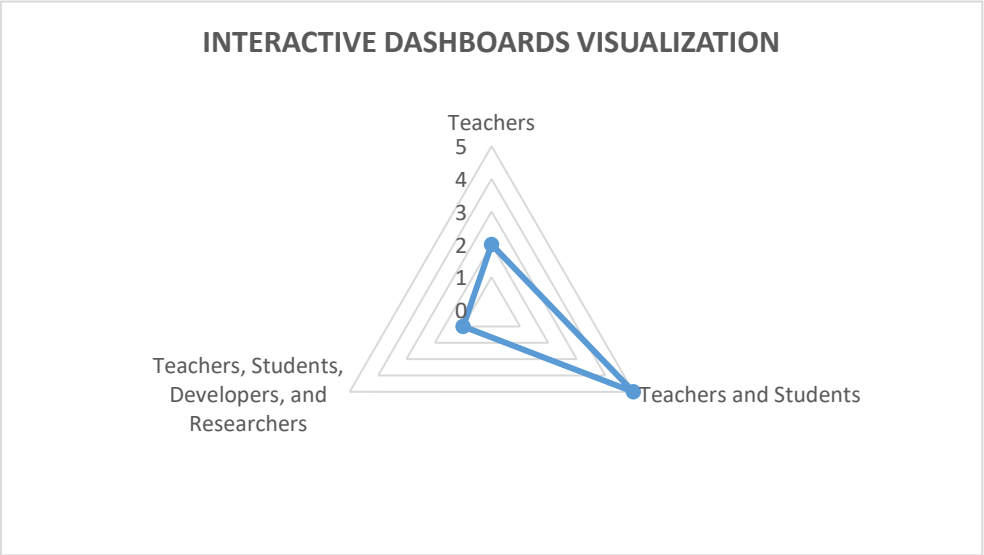

Figure 5 – Interactive dashboards for educational visualization.

6. Final Considerations

The study aimed to present and analyze the evolution of studies associated with the use of interactive learning analytics panels in serious games through an SLR, resulting in 75 selected studies which made it possible to deepen the researched subject.

By means of bibliometric analysis and descriptive analysis, it was possible to observe relevant data for the investigation, such as the growth in the use of interactive dashboards in the presentation of data in serious games and the use of interaction models to track educational data.

The information visualization must take into account each person involved in the teaching and learning process. On top of that, it is necessary that the serious game provides the values and information of the game immediately and with a minimum configuration (Alonso-Fernandez et al., 2017), so that actors such as teachers can visualize the results quickly and easily. It is also necessary to make it possible for advanced users to customize and adapt their analyzes to specific requirements (Alonso-Fernandez et al., 2017), in order to visualize what they deem most necessary about their performance.

Regarding the number of publications per year, the growth trend of the learning analytics in serious games subject in the last years is notable. The number of citations shows a great concern with the tracking of educational data. The types of studies investigated have an increasing demand in studies related to educational technologies. Finally, with regards to data visualization, it is possible to conclude that studies related to the use of interactive dashboards in serious games have been growing, but the main focus remains on teachers/instructors and students/participants. Thus, there is a need for greater versatility in learning analytics frameworks in order to take into account other actors that are part of the teaching-learning process such as game developers/designers and managers/researchers.

7. Acknowledgement

The research was financed by CAPES – Brazil and Federal University of Santa Catarina (UFSC).

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Appendix A

Classification and Authors	Research question/Purpose	Visualization techniques	Results summary	Citations
(C1) Serrano-Laguna *et al.*, 2014	They propose two main steps for the application of learning analytics: identification of generic report tracking and construction of game-specific evaluation rules based on generic combinations.	N/A	The game was evaluated by a group of 37 students from a web programming team. 94% of students successfully completed the game and 81% of students achieved satisfactory scores.	30
(C1) Freire *et al.*, 2014	Investigates issues involved in integrating serious games within the Massive Open Online Course (MOOCs).	N/A	The test content was integrated and the adopted model was analyzed, but an experimental validation was not carried out.	15
(C1) Alonso-Fernández, Caballero Roldán, *et al.*, 2019	They propose a combination of game learning analysis and data mining techniques to predict knowledge change based on student interactions.	N/A	The prediction model was highly accurate, and the authors suggest that serious games should be used not only to teach, but also to measure knowledge acquisition after the game.	14
(C1) Rodríguez-Cerezo *et al.*, 2014	It describes the system entitled Evaluators, which allows instructors to generate games related to exercises that address concepts of computer languages.	N/A	By reproducing the generated games, students were able to learn the fundamentals of the semantic evaluation process in attribute grammars.	12
(C1) Liu *et al.*, 2017	Investigates students' behavior patterns when interacting with an adaptive learning environment.	V1	They concluded that the lack of alignment between components in an adaptive system can impact how students access the system and how visualizations can reveal interesting results.	7
(C1) Hubalovsky, Hubalovska & Musilek, 2019	Describes learning exercises containing implemented adaptive elements.	N/A	The authors concluded that adaptive learning resources can be implemented in primary education.	5
(C1) Ruipérez-Valiente *et al.*, 2017	Presentation of a learning analysis tool for Open edX, entitled Analyze.	V1	The research obtained very positive results for a usability scale (78.44 /100) regarding the usefulness of the visualizations (3.68/5) and the effectiveness ratio (92/100) of the actions.	5
(C1) Nguyen, Gardner & Sheridan, 2018	It proposes a structure for serious games specialized for people with intellectual disabilities.	N/A	Provides necessary guidance for potential application developers for people with intellectual disabilities.	4
(C1) Cano *et al.*, 2018	It addresses the use of a serious game to train students with intellectual disabilities on trips on the subway.	V1	The game is evaluated through activities, being considered then a supplementary tool to train skills on the subway.	4
(C1) I. J. Perez-Colado *et al.*, 2017	It presents the creation of uAdventure, a serious game editor, which allows the creation of games without the need of programming.	N/A	The authors noted that uAdventure improves the lifecycle of serious games, reducing creation and maintenance costs.	4
(C1) Hauge *et al.*, 2015	Explores the potential in the use of games and learning analytics in support of teaching and learning experience.	V1	The results showed that 94% of students completed the game successfully.	4
(C1) Park *et al.*, 2016	Features a serious game for children with Attention Deficit/Hyperactivity Disorder (ADHD).	N/A	The platform is expected to help children with ADHD improve their level of attention, control hyperactive behavior and develop their social skills.	4
(C1) Terras *et al.*, 2018	Synthesizes the literature on the use of serious games for people with intellectual disabilities.	N/A	The authors concluded that the contextual influences on gameplay are complex and dynamic.	3

Classification and Authors	Research question/Purpose	Visualization techniques	Results summary	Citations
(C1) Calvo-Morata *et al.*, 2018	Describes the serious game intitled Connected by presenting a validation process with students through game analysis.	V1	The game makes users aware of cyberbullying and makes players empathize with victims.	3
(C1) Alonso-Fernández, Cano *et al.*, 2019	It presents the experience of raising awareness of cyberbullying through a serious game.	V1	It tests some hypotheses defined by the educators and simplifies the implementation and evaluation of the game through learning analytics.	2
(C1) Seufert *et al.*, 2019	It investigates how learning analytics can be applied in the pedagogical area and conceptualizes a generic structure for the design of learning analysis environments.	N/A	A pilot project was applied to validate and review the generic model and for each case study (n = 4) the planning was carried out with specialists.	1
(C1) Loh & Li, 2016	Investigates how to reduce training costs with serious games.	N/A	Data-driven training can help learning organizations to reduce costs by decreasing unnecessary training.	1
(C1) Ninaus *et al.*, 2014	Uses infrared spectroscopy to examine whether neurophysiological measures can help to identify if a user is learning during a game.	N/A	Identification of increased brain activation in frontoparietal areas, while users actively learn rules or applied knowledge during the game.	1
(C1) V. M. Perez-Colado *et al.*, 2018	Describes fundamental specifications for location-based games.	V2	The authors concluded that the xAPI library is a simple, effective, standards-based and extensible way to handle the exchange of learning analytics data between location-based games.	1
(C1) Codish, Rabin & Ravid, 2019	Presentation of a methodology for detecting patterns of user behavior in unstructured processes.	N/A	The authors concluded that the proposed methodology has the ability to discover specific user usage patterns and to create a cluster based on the identified patterns.	0
(C1) Capatina *et al.*, 2018	Presentation of an environment to track the learning analysis on the performance ranking of serious game teams.	N/A	The authors concluded that one can develop skills for real business competition.	0
(C1) Forsyth, Graesser & Millis, 2019	Investigation of shallow versus deep learning predictors in a serious game known as Operation ARA.	N/A	The results revealed distinct patterns of predictors of deep versus superficial learning for students in the game's training environments.	0
(C1) Birt, Clare & Cowling, 2019	It explores the pedagogical possibilities in a case study based on mixed reality multimodal learning analysis, enabled for smartphones for health education, focused on learning the anatomy of the heart.	V1	The results of the pilot study showed engagement and enthusiasm of the proposed method among experts, but also demonstrated problems that must be overcome in the pedagogical method before implementation.	0
(C1) Liu *et al.*, 2019	It explores the extraction of data captured by an educational digital game, designed for high school, in order to identify students' behavioral patterns when using the game.	V1	The results showed positive relationships between student performance and the use of tools in terms of frequency and duration of use of the tool.	0
(C1) Francis *et al.*, 2019	It presents a critical thinking about the analysis of learning.	N/A	The authors presented the impact of student learning analysis, showing that it is limited and confined to research studies.	0
(C1) Calvo-Morata *et al.*, 2019	Describes the experience using game learning analytics to encourage the application and deployment of serious games in the classroom as learning tools.	V3	The authors concluded that to simplify the application and the implantation of games by the educators, a clear benefit in terms of utility and contribution must be provided.	0
(C1) Martínez-ortiz *et al.*, 2019	It seeks to increase the engagement of software engineering students through	V1	It was described the design of a class management web application implementation that allows dynamic changes in multilevel	0

Classification and Authors	Research question/Purpose	Visualization techniques	Results summary	Citations
	gamification.		analysis.	
(C2) Gibson & de Freitas, 2016	Analyzes and evaluates virtual performance based on games and data analysis.	N/A	The authors presented the importance of learning analysis when intensive mixed methods are adopted.	14
(C2) Rowe *et al*., 2017	It presents an evaluation proposal that allows recording behaviors and game data for the measurement of implicit learning.	N/A	The authors concluded that the measures of learning implied within the evaluated games, were significantly correlated with improvements in external post-test evaluations.	12
(C2) Klemke, Eradze & Antonaci, 2018	It presents evaluations for the first selection of elements of a serious game suitable for the Massive Open Online Course (MOOC).	N/A	The authors identified ten suitable game elements to be applied in the MOOC environment.	5
(C2) Mora, Caballé & Daradoumis, 2016	It presents the construction of a multifaceted electronic evaluation structure.	N/A	The authors provided a complete assessment of the participants' actual performance based on the proposed evaluation structure.	5
(C2) Chaudy & Connolly, 2018	EngAGe presents an evaluation mechanism designed to separate the game from its evaluation.	V3	The evaluation indicated that, having access to EngAGe, educators would be more likely to trust the evaluation of a game.	2
(C2) Serrano-Laguna *et al.*, 2018	It presents a methodology to evaluate the effectiveness of a game based on non-disruptive tracking.	N/A	The authors concluded that the methodology allowed to evaluate the levels of effectiveness of the game and to identify problems in the design.	2
(C2) Cariaga & Feria, 2016	It presents a proposal for evaluating educational games through learning analytics.	V1	The authors concluded that the challenges of learning analytics are related especially in the privacy and ethics of data.	2

Classification and Authors	Research question/Purpose	Visualization techniques	Results summary	Citations
(C2) I. J. Perez-Colado *et al*., 2019	Describes the most common problems encountered when validating games and introduces Simva, a tool designed to simplify the process of validating serious games.	N/A	Simva proved to be effective in simplifying data collection and processing, being faster and automating some of the most error-prone processes.	1
(C2) Slimani *et al.*, 2018	Collects and analyze experience data from the educational game Elisa for teaching the English language.	V1	Provided students' performance levels through clustering and data visualization methods.	1
(C2) V. M. Perez-Colado *et al*., 2019	It presents the first evaluation of uAdventure, an easy-to-use game development environment for graphic adventure narrative games.	N/A	The results of the evaluation, presented a creation of simple stories for profiles that had no previous knowledge of the mechanism and presented a positive feedback for more technical profiles that would use the tool as a prototyping model for complex projects.	1
(C2) Georgiadis *et al*., 2019	It proposes a generic tool for the arrangement of stealth assessment, in order to remove its current limitations and pave the way for its wider adoption.	N/A	In a controlled test condition, the accuracy of the stealth rating was inherently stable and high (usually above 92%).	0
(C3) Serrano-Laguna *et al*., 2017	Presentation of an interaction model that establishes a basis for the application of learning analytics in serious games.	N/A	The article presented a new interaction model to track serious games and their implementation with the xAPI specification.	30
(C3) Hauge, Berta, *et al*., 2014	It addresses the implications of combining learning analytics and serious games in the pursuit of game improvements.	N/A	It addressed how to improve the quality and progress of the game, as well as, monitor and evaluate the player's behavior.	10
(C3) Villagrá-Arnedo *et al.*,	The authors demonstrates that the complementation of behavioral data with	N/A	The system was able to otbain a weekly classification of each student with the	8

Classification and Authors	Research question/Purpose	Visualization techniques	Results summary	Citations
2016	other more relevant data, can lead to a better analysis of the learning process.		probability of belonging to one of the three classes: high, medium and low performance.	
(C3) *Staubitz et al*., 2017	It presents a gamification process carried out on a MOOC platform.	N/A	With the use of gamification, it was possible to use the discussion forum as a kind of "soft" exercise.	5
(C3) Chaudy *et al*., 2014	It features a mechanism to be used by serious game developers and teachers.	V1	The presented solution acts as a communication tool between developers and educators.	4
(C3) Ganan *et al*., 2016b	It proposes a solution to satisfy the requirements in terms of software artifacts.	N/A	The authors presented the first steps in the development of an e-learning platform called ICT-FLAG.	4
(C3) I. Perez-Colado *et al*., 2018	It manages multilevel analysis through improvements in policy and in the mechanism for introducing analytical models of meta-learning.	N/A	Learning objectives can be shared between different sub-games.	3
(C3) Pérez-Berenguer & García-Molina, 2018	Development of the UPCTforma tool, whose main objective is interoperability.	V3	The innovative aspect of the proposed architecture was the transformation of tracking data into "learning analytics models".	3
(C3) Hauge, Kalverkamp, *et al.*, 2014	It analyzes under what circumstances an online game, produced for a particular course, could be integrated in an easy and non-facilitated way.	N/A	The learning outcome is shown to be random, and it is expected that only students with prior knowledge will be able to place the observed content in the right context and thus learn about the impact of their decision through the game.	2
(C3) Ganan *et al*., 2016a	It presents the implementation of the ICT-FLAG platform and reports the first experiences of connection and integration of	N/A	The authors reported the experiences with the innovative web-based e-learning platform which combines gamification and learning	2
Classification and Authors	**Research question/Purpose**	**Visualization techniques**	**Results summary**	**Citations**
	the platform with a real e-learning tool.		analytics.	
(C3) Callaghan *et al*., 2018	It presents an extension to the ATMSG framework that facilitates the identification, selection and integration of analyzes in serious games.	N/A	The framework was able to identify the gameplay and performance challenges.	2
(C3) Santamaría-Bonfil *et al*., 2019	It presents the development of an ecosystem for training line operators in maintenance maneuvers, using the Experience API standard, Big Data components and learning analytics.	N/A	The results have shown that a suitable domain model to customize the training path of the power line players can be built directly from legacy text data.	1
(C3) Cano *et al*., 2016	It analyzes necessary processes to develop a serious game for the training of people with intellectual disabilities to get around the city using public transportation.	N/A	The authors concluded that applications related to Game Learning Analytics (GLA) models and learning analytics techniques, such as clustering or predictive techniques, are necessary in future analyzes.	1
(C3) Calvo *et al*., 2016	It analyzes factors that contribute to the total cost in a serious game and proposes strategies to keep it in line with the requirements.	N/A	The authors concluded that specific assessment resources for behavior analysis make the game expensive.	1
(C3) Kim & Moon, 2018	It presents a model that makes it possible to identify activities based on a series of apprentice actions over time.	N/A	The model was able to offer a view on the continuity and persistence of objects, for the understanding of teaching-learning activities.	1
(C3) Azcona, Hsiao & Smeaton, 2019	It presents a research methodology to detect students at risk of failing in computer programming modules.	V3	The methodology allowed the construction of a predictive model using static information from the students.	1
(C3) Alachiotis, Stavropoulos &	Analyzes data from the Modular Object-Oriented Dynamic Learning Environment	V3	The results showed the students' interest in each structural component, their dedication to the	0

Classification and Authors	Research question/Purpose	Visualization techniques	Results summary	Citations
Verykios, 2019	(Moodle) by tracking students' daily and weekly activities.		course and their participation in the forums.	
(C3) Shoukry & Göbel, 2019	It presents the design and development of "StoryPlay Multimodal", a mobile platform for multimodal analysis for the evaluation of serious games.	V3	The platform was able to describe how the multimodal data can be captured in a discreet way for the evaluation of serious games.	0
(C3) Chaudy & Connolly, 2019	Presents the benefits of EngAGe for game developers.	V3	The results showed significant differences in usability between beginning and experienced developers, but did not show differences in terms of usefulness.	0
(C3) Ali *et al*., 2018	It presents the use of serious games with learning analytics in the domain of product marketing.	N/A	The authors concluded that based on the user's decisions, the company can obtain customer choices, feedbacks or marketing results and make decisions based on the results.	0
(C3) Skalka & Drlík, 2019	It presents the architecture of a system for teaching and learning programming based on interactivity and modern educational approaches.	N/A	The authors described the structure of educational content divided into levels, according to the architecture of the system.	0
(C3) Morata *et al*., 2019	Features the life cycle description of serious games designed to be used in tasks.	N/A	Educators' tasks were able to be simplified to: initial game validation; application in an effective and controlled manner; and automatic assessment based on the student's actions in the game.	0
(C3) De Oliveira & Santos, 2016	The authors present a virtual teaching and learning environment, called Problem-based Learning (PBL) Master.	N/A	As a result of the maturity acquired in xPBL, it was possible to define the requirements and the implementation of the PBL Master.	0

Classification and Authors	Research question/Purpose	Visualization techniques	Results summary	Citations
(C4) McCoy, Lewis, & Dalton, 2016	The authors present the benefits of using gamified training platforms for medical education and training.	N/A	The authors demonstrated better learning results with virtual patient simulations.	22
(C4) Vieira, Parsons, & Byrd, 2018	Analyzes visual learning through educational data.	N/A	The authors concluded that just a few studies bring visual learning analysis tools to classroom environments.	18
(C4) Mavroudi, Giannakos & Krogstie, 2018	The authors present future developments, challenges and opportunities in the area of adaptive learning using learning analysis.	N/A	The authors concluded that there is a need for more research on the topic in specific domains and configurations of learning.	7
(C4) Alonso-Fernández, Calvo-Morata *et al*., 2019	How the data is applied in a technical way taking into account analytical learning in serious games.	N/A	The authors concluded that serious game interaction data can reduce the complexity of the area, simplifying the game's design and development, and measuring the real impacts of the games.	4
(C4) Montoro *et al*., 2019	It proposes a meta-analysis in the area of social sciences and emerging technologies.	N/A	Scientific production on emerging technologies is related to collaborative learning, deep learning, adaptive learning, learning analytics, and e-learning.	2
(C4) Buenaño-Fernandez *et al*., 2019	Analyses the use of data mining tools for decision making in engineering education.	N/A	They concluded that there is currently a trend towards case study research, which is more directed towards software engineering and computer science.	1
(C4) Petrov *et al*., 2019	Investigation of new relationships to the educational process, learning analytics and serious games.	N/A	When learning analytics and serious games work together, positive influence can be gained in areas of education.	0

Classification and Authors	Research question/Purpose	Visualization techniques	Results summary	Citations
(C4) Massa & Kuhn, 2019	Investigation of applications in real learning environments.	N/A	The development of serious games and their application in the real learning environment is promising, but quite poor in terms of the resources used for its implementation.	0
(C5) Melero *et al.*, 2015	Application of visualizations for self-assessment.	V1	The students obtained a significantly higher score in the post-test using visualization resources than in the pre-test without using visualization resources.	29
(C5) Alonso-Fernandez *et al.*, 2017	It presents two main steps for the systematization of games in learning analytics.	V3	They presented two important steps to achieve the systematization of games: The use of the Experience API library (xAPI) and a set of data visualizations.	12
(C5) *Minović et al.*, 2015	Presentation of a learning visualization tool in a serious game.	V1	Based on the findings the participants of the case study were in favor of the proposed approach and justified additional investments in the development of the method.	12
(C5) Bull & Wasson, 2016	Presentation of a tool for visualizing language learning skills for students and teachers.	V1	Data visualization helped students to reflect and monitor their learning and teachers in the decision-making process.	8
(C5) Serrano-Laguna & Fernández-Manjón, 2014	The authors introduce educational video games as class exercises in face-to-face education.	V1	The approach met the proposed needs. Objective-oriented visualizations helped the teacher to have a complete view of student performance.	2
(C5) I. J. Perez-Colado *et al.*, 2018a	It presents the functional implementation of a multilevel analysis (MLA).	V2	With the framework it was possible to obtain functionalities to track and evaluate game scenarios at various levels.	0

Studies Classification: **C1**: Studies with an Emphasis on Educational Technologies; **C2**: Proposals for Evaluation Methodologies; **C3**: Studies with an emphasis on Computational Technologies; **C4**: Literature Review Studies on Learning Analytics; **C5**: Studies with an Emphasis on Data Visualization.

Visualization techniques: **V1**: Visualization through static dashboards with individual results and/or group of users; **V2**: Visualization through hierarchical maps; **V3**: Visualization through interactive dashboards with individual results and/or group of users; **N/A**: Not applicable.