An overview of Game-based learning studies and their relationship to student engagement

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Abstract: The use of games in education has grown due to its contribution to the learning process through promoting student interest and participation provided by its elements. Game-based learning (GBL) emerges as a learning theory consisting of concepts, methodology, and application for learning and teaching. Several studies report that the use of GBL had positive efficacy for the learning process and that it engaged the student. However, it is not very common for authors to seek to understand how the student engagement promoted by GBL influenced the learning process. Therefore, this article presents a systematic mapping of the literature of evidence of engagement promotion by GBL and methods and techniques for measuring engagement levels. A search for studies in seven indexers was made, with 627 results, and of these, thirteen were selected for analysis based on a set of specific questions. The results of this article explain the types of evidence of engagement, the most identified types of engagement, and the methods of learning analytics, educational data mining or statistics used to measure and understanding the engagement.
Keywords: Education, Educational Technology, Feedback, Learning Strategies, Learner Autonomy.

1. Introduction

Among the pedagogical methodologies that emerged from emerging studies on the use of games in education, there is game-based learning (GBL), which centers on the "conception, development, use and application of games in education and training" (CARVALHO, 2015, p. 1). This pedagogical method can undo the incompatibility between traditional education and digital learning that is usually consolidated when the student shapes their expectations about learning based on the process (cognitive skill development) that occurs within games, as it proposes the union of games motivation with curriculum content (PAPASTERGIOU, 2009). Papastergiou also adds that games with educational goals and content can provide smooth, pleasant, and effective learning, placing the student at the center of the process.

In the execution of the learning process supported by game-based learning, a variety of student interaction data in the game is generated. This data can be collected to provide the educator with better visibility into student action (ALONSO-FERNÁNDEZ *et al.*, 2019). From this data, through using educational data mining (EDM) or learning analytics (LA), there is an opportunity to explore and understand learning from different angles (SIEMENS, 2013).

This study aims to map the literature regarding research that addresses game-based learning and seeks to identify or measure student engagement in the learning process through EDM or LA techniques. Therefore, these are the research questions: What is the scientific evidence on game-based learning application as an

artifact promoting student engagement in the learning process? How can EDM or LA techniques promote the measurement of student engagement levels while using games?

2. Theoretical foundation

Games have the potential to be applied in education, as they aim to "strengthen the learning process, intending to arouse interest, curiosity, and participation in individuals, and also to use modern and pleasurable elements to carry out tasks and for the achievement of goals" (SILVA; PIMENTEL, 2021). Given the possibilities that games offer for education, game-based learning emerges as a theory of learning with conception, method, and application for the members of the teaching-learning process (CARVALHO, 2015). Games created based on this theory can also be characterized as Serious games (CARVALHO, 2015) since they were developed with a focus on educating or training the user, usually from the combination of concentration required by challenging activities and the pleasure experienced by self-overcoming (HAMARI *et al*., 2016).

The use of game-based learning is a possible solution to student disengagement, as educational games are efficient to present the problem interestingly and also to promote student engagement and immersion in the process (HAMARI *et al*., 2016). However, there is a complexity in applying this theory. For proper use, proper appropriation of the game-based learning concept is expected, such as, for example, the teacher mastering what he will explore during the process and the connection between the pedagogical-didactic objectives and the established pedagogical methodology (SILVA; PIMENTEL, 2021).

One of the studies that can be mentioned and reinforces the relationship between the application of game-based learning and student engagement is the research developed by Silva and Pimentel (2021), where they collected data regarding the planning of classes, production of material, and use in class by teachers from a private school in Maceió, in Alagoas-Brazil, who used game-based learning. This study enabled an understanding and evaluation of the application with children and concluded that this pedagogical methodology contributes to student engagement (SILVA; PIMENTEL, 2021).

As student engagement is one of the points of this study, its concept will be adopted as the level of interaction and interest presented in the educational and school environment (AKEY, 2006). The literature portrays three types of engagement: behavioral, emotional, and cognitive (FREDRICKS *et al*., 2004). Seixas (2014) categorizes student engagement based on three types mentioned below.

- Behavioral engagement: Involves the participation and involvement of students in school and extracurricular activities and the positive behaviors undertaken by students during the resolution of activities.
- Emotional engagement: It involves the affective and emotional reactions of students to activities, subjects, and other elements that make up the school environment.
- Cognitive engagement: Involves the student's psychological investment in learning.

Measuring student engagement during activities in the educational environment is a challenge for scholars (SEIXAS, 2014). In search of a way to measure this psychological phenomenon, authors use other resources, such as questionnaires (ZEPKE *et al*., 2010), interviews (SULLIVAN *et al*., 2009)(WILLEKENS; GIBSON,

2010), number of interactions in a virtual environment — in studies of this type (ISMAIL *et al*., 2021), or even other psychological theories, such as the flow theory (HAMARI *et al*., 2016).

The educational sector generates a large amount of data from the use and interaction with technological resources. If properly collected and analyzed, it is possible to explore those data to understand student learning and pedagogical decision-making (ROMERO; VENTURA, 2013). Data mining shows promise to develop this exploration (ROMERO; VENTURA; GARCIA, 2008). According to Romero and Ventura (2013), educational data mining

> "is concerned with developing, researching, and applying computerized methods to detect patterns in vast collections of educational data that would otherwise be difficult or impossible to analyze due to the enormous volume of data within which they exist" (ROMERO; VENTURA, 2013, 12).

Analytics is an approach that "can be applied to help scientists, researchers, and academics understand the connective structures that underpin their field of knowledge" (SIEMENS, 2013, p.1381). Learning Analytics (LA) has emerged as a promising and contributing research branch for everyone involved in the educational area, as it makes it possible to identify how students act or feel within a virtual environment and how they learn (ISMAIL *et al*., 2021).

Currently, Baker, Gasevic and Karumbaiah (2021) state that the definition of LA established by the organizing committee of the 1st edition of LAK, "the measurement, collection, analysis, and reporting of data about students and their contexts, with the purpose of understanding and optimize learning and the environments in which it takes place", is commonly used. The interest in AL practices to increase and evaluate the efficiency of educational technologies and virtual learning environments has been growing (BAKER; GASEVIC; KARUMBAIAH, 2021) because, from data generated by these media, AL enables to predict crucial points for the teacher, such as the academic performance and even the dropout rate of students (ISMAIL *et al*., 2021).

3. Method

Initially, the research platforms ACM Digital Library, IEEE Xplore, and ScienceDirect were searched for mappings or systematic reviews in English that addressed the topics: game-based learning, engagement, and learning analytics.

After the search, there were no results from the IEEE Xplore and Sciencedirect databases, but ACM returned 11 results. Of those results, none corresponded to a mapping or review of the selected topics. Thus, the search was expanded to the abstracts and citations databases: Scopus and Web of Science. Three results were obtained, of which only one was a mapping, and addressed the topic of artificial intelligence in education. The other two results were a systematic review on LA and Serious Games (DE OLIVEIRA FASSBINDER *et al*., 2017) and a systematic review on the MOOC's approach in the context of software engineering education (LIU *et al*., 2017). Therefore, from the initial search, there are no systematic mappings that address the object of this study.

Three specific questions were determined to delimit the discussion of the results obtained after applying the inclusion and exclusion criteria of the articles found in the search stage: (SQ1) In the articles, was student engagement measured/identified? How was it classified?; (SQ2) Which data mining/LA/statistics techniques were used in the

studies?; (SQ3) What is the nature of the variables used in the studies?

3.1 Search for articles

Firstly, search platforms were selected to start the search for articles. The selected platforms were *IEEE Xplore*, *ACM Digital Library*, *ScienceDirect*, *Scopus*, *Web of Science*, *SpringerLink*, and *Scholar Google*. The search for articles on these platforms took place using strings. The string used was as follows: ("Game" OR "Game-based learning") AND ("Learning Analytics" OR "LA" OR "Analytics" OR "Educational data mining" OR "EDM") AND ("Engagement" OR "Disengagement"). In addition, the search for works published between 2011-2021 was delimited. The results were: IEEE *Xplore* (52), *ACM Digital Library* (9), *ScienceDirect* (32), *Scopus* (203), *Web of Science* (96), *SpringerLink* (187), and *Scholar Google* (30). The real value of results in the search performed on the SpringerLink and Scholar Google databases was 18825 and 344000, respectively, and that is why it was necessary to go through the first 187 and 30 results and select them.

3.2 Selection of articles

Chart 1 shows the inclusion and exclusion criteria for articles. It was established and applied in stages to filter the returned studies.

Stages	Inclusion criteria	Exclusion criteria
1	Categorized by the database as an article (article or conference article).	Categorized as other documents than an article (book chapter, final report, among others).
2	Written in English.	Not written in English.
3	Research in education.	Game application approach in another area.
4	An approach that connects game-based learning and student engagement.	Game-based learning application focusing on theoretical issues only.
5	Use of EDM or LA or statistical techniques to measure/identify student engagement or pedagogical decision making.	It presents the use of LA or DM or statistics focused on the development or design of games.

Chart 1 - Inclusion and exclusion criteria

After applying the inclusion and exclusion criteria, 13 articles were able to contribute to this study. Figure 1 presents the description of the application of the criteria.

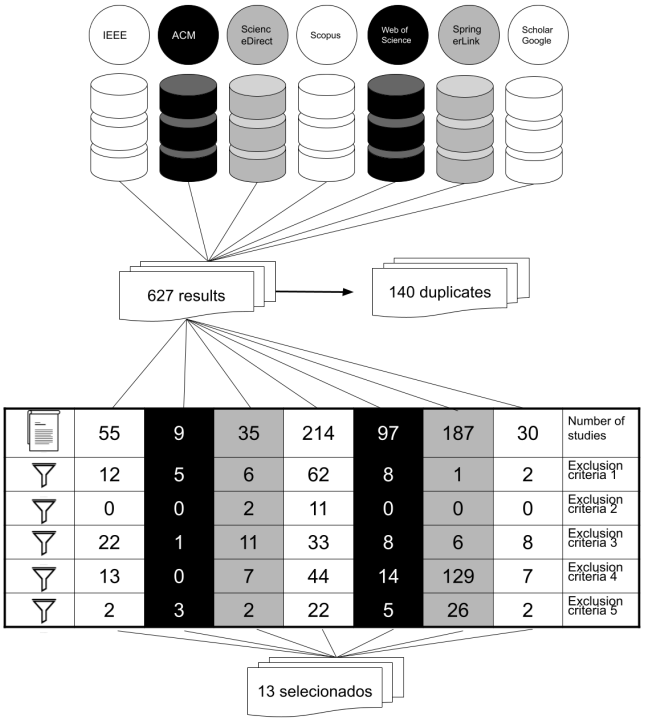


Figure 1 – Application of the exclusion criteria

Among the 627 results, 140 duplicates were removed before applying the criteria. According to the exclusion criteria, it is clear that criterion number 4 was the most discarded article. During the application of the fourth filter, 207 articles were excluded. After the 13 were selected, analyzes were started, guided by specific research questions.

4. Results and discussions

This section exposes data from the analysis of the 13 selected articles (Chart 2) after the inclusion and exclusion criteria applied on the results of the searches carried out in the databases.

Identifier	Article title	Author(s)
[A1]	Using game analytics to measure…	Callaghan, M. J. et al.
[A2]	Learning analytics through a digital …	Cariaga, A. A.; Feria, R.
[A3]	Patterns of Engagement in…	Ruipérez-Valiente, J. A. et al.
[A4]	Effects of solo vs. collaborative play in a…	Ruipérez-Valiente, J. A.; Kim, Y. J.
[A5]	Towards design guidelines for…	Fracaro, S. G. et al.
[A6]	Improving Learners' Assessment…	Daoudi, I. et al.
[A7]	The Role of Active Engagement of…	Chiu, H. Y. et al.
[A8]	Social engagement in a digital…	Bonvin, G.; Sanchez, E.
[A9]	The roles of engagement and…	Chen, C. H. et al.
[A10]	Multimodal learning analytics…	Emerson, A. et al.
[A11]	Detecting patterns of engagement…	Ober, T. M. et al.

[A12]	In-Game Actions to…	Moon, J., & Ke, F.
[A13]	Challenging games help students…	Hamari, J. et al.

Chart 2 - Articles selected for analysis

The selected studies were analyzed, seeking to answer the research questions. The following subsections will describe the detailed analysis of each question.

4.1 SQ1: In the articles, was student engagement measured/identified? How was it classified?

In this specific question it was sought to identify the studies concerned with identifying/measuring the engagement of research participants.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
CP			x	x			x	x	x		x		
EM						x				x			x
CG												x	
SO			x					x					
CT												x	
NE	x	x			x								

Chart 3 - Engagement Types Identified

The results in Chart 3 show that behavioral engagement (CP) is the type of engagement most identified by the authors of the selected articles. This demonstrates that such studies are within the prevailing conceptual consensus in the academic literature, which consists of three distinct and interrelated dimensions of engagement: behavioral, emotional (EM), and cognitive (CG) (FREDRICKS *et al*., 2016b).

Although the non-empirical works [A1], [A2], and [A5] do not specify (NE) the characterization of the engagement promoted by the suggested approach, they tend to advise the application of the behavioral engagement perspective, since they propose to analyze the actions or behaviors of students in the game.

According to Fredricks et al. (2016b), literature shares the idea that engagement is a multidimensional concept, and it is possible to observe the emergence of different dimensions from the three already mentioned: social engagement (SO) and content engagement (CT). Social engagement is a branch of behavioral engagement, which is concerned with an individual's social behavior, according to [A8]. Content engagement "represents how students apply procedural and conceptual knowledge only through game requests" (MOON; KE, 2020, p. 865). By this definition given by Moon and Ke (2020), content engagement can be classified as a derivative of cognitive engagement, as the authors report that this type of engagement is strongly associated with the mental process of students.

4.2 SQ2: Which data mining/LA/statistics techniques were used in the studies?

Initially, it was noticed that some of the selected articles used techniques from different categories. Seven of them combined AL and statistical techniques (Chart 4). This fact is consistent with Cooper's LA concept brought by Siemens (2013), which highlights that "Analytics is the process of developing actionable perceptions by defining problems and

applying statistical models and analysis concerning existing and/or simulated futures" (p. 1382).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
LA	x		x	x	x		x	x		x	x	x	
EDM			x			x							
STA			x	x		x	x	x	x	x	x	x	x

Chart 4 - Combinations of Techniques Categories

Article [A2] did not present any technique in its proposal. Articles [A3] and [A10] present cluster analysis, which was expected since it is AL's primary area (SIEMENS, 2013). Tracking analysis is found prominently in [A1], [A4], and [A8], as they are studies that focus on the analysis of the individual's behavior within the game. The statistical techniques found when analyzing articles [A3], [A4], [A7], [A9], and [A10] were Pearson's correlation, analysis of variance, and Cohen's D. Such statistical techniques were used to verify the relationship of engagement with other relevant aspects of each research (learning performance, game retention, stress level).

Given the need to analyze data from student engagement, studies have been developed on how to measure and analyze behavioral and emotional data from those involved (FREDRICKS *et al.*, 2016a). Therefore, during the analysis of these articles, the use of techniques and theories that deserve attention can be observed. Latent class analysis, thematic analysis, and structural equation modeling are the unique techniques noted in [A11], [A12], and [A13], respectively. The latent class analysis and structural equation modeling demonstrated efficiency in the emotional analysis item in categorical variables.

4.3 SQ3: What is the nature of the variables used in the studies?

This subsection sought to identify and highlight variables in the selected studies that helped identify or measure student engagement. In seeking to define and measure student engagement, it is essential to develop appropriate techniques that take a multidimensional perspective to examine types of engagement and how other aspects of the context relating to them (WANG *et al.*, 2016).

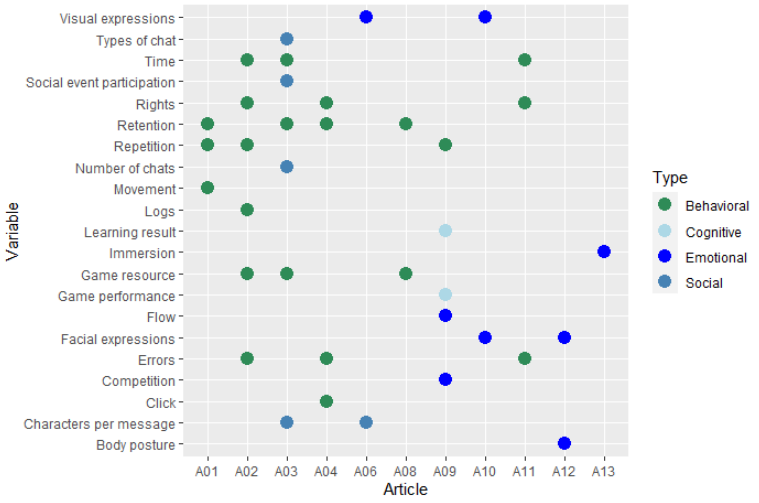


Figure 2 - Variables that were related to student engagement

In Figure 2, it is possible to notice several variables (9) of the behavioral type extracted from a GBL environment. A quantity already expected as a consequence of the selected articles, as they address more behavioral type engagement (Chart 4).

The variables found in articles [A3] and [A6], which cover the "social" type variables, are aspects arising from behavioral characteristics within the game. However, behaviors aim at the relationships that individuals establish with each other in the GBL environment. And the understanding and appropriation of these aspects are essential because

> "[...] the interaction between these social possibilities for game-based learning requires further investigation to provide better insights into how these choices influence students' game behavior and learning outcomes" (Ruipérez-Valiente; Kim, 2020, p. 2).

According to Figure 2, the article [A8] does not present any variable of the social type, although, according to Chart 3, it has addressed social engagement in its research. The authors of [A8] measured social engagement based on decisions made by students in the *Classcraft* game, where, through tracking analysis, they verified student decisions in choosing to acquire a collaborative or individual "power". Thus, the measurement of social engagement, in [A8], was based on the individual or collective choice of "powers" (*Classcraft* game resources) by students.

In the article [A6], the authors state that emotional processes can impact the learning process. The application of AT on the behavioral aspects in the game associated with other emotional aspects, such as those mentioned in Figure 2, can provide better accuracy of the prediction methods regarding the learning performance and level of engagement (EMERSON *et al*., 2020).

The absence of articles [A5] and [A7] in Graph 2 is noticeable. Article [A5] is a non-empirical, however, although it highlights the use of AL in the process as essential, it does not describe which variables should be considered for measuring the engagement state. The [A7] measures the active engagement of medical students by the number of observations recorded by the peers who watched the peer performing surgical operations in the RV. This article is not present in Figure 2 because the results do not include the association of this variable to the serious game. That is, the exact relationship between the game and engagement is not perceived.

5. Conclusions

The mapping contributed to the scientific community, as it seeks to understand aspects that relate games to student engagement and methods or techniques that help in understanding and measuring engagement. The results show the scarcity in the literature of research that answers the questions raised in this article. Considering the information collected in the analysis process, understanding the concept of engagement and its identification and measurement are points that can contribute to filling gaps in the students' learning process when using games for teaching.

One point that stood out was: 84,61% of the selected articles used data mining techniques, LA, or statistics for identification or measurement. This point is noteworthy since many studies were limited to using questionnaires applied before and after the application of games and identified engagement based on the students' self-report, which 11 articles appropriated immediate data collected during the application process to identify or measure engagement. Although the articles [A4], [A6], [A9], [A10], and

[A13] used a questionnaire, they used this data as validation or complement to the data extracted from the game.

Relating the type of engagement and the variables associated with engagement, it is clear that human behavior is the principal lens to identify individual engagement since the most identified type of engagement was behavioral (Chart 3), and these variables were present in most researches (Chart 4). Studies that focused on these aspects have tended to use EDM or LA since the individual's behavior in the game is recorded as a digital trail.

Student engagement has the potential to assist the teacher or researcher in better understanding the learning process. Therefore, the more the researcher appropriate the engagement in question, the greater will be the understanding of the opportunities offered by this psychological aspect. In the selected articles, only 38,46% identified the type of engagement or psychological state similar to or derived from the engagement, and the others could have optimized their research if they had appropriated themselves properly.

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