

Review

Influence of Game-Based Learning in Mathematics Education on Students' Affective Domain: A Systematic Review

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Abstract: In modern education nowadays, the use of game-based learning as a teaching and learning method is popular in all school subjects, including mathematics. There are numerous studies dealing with the influences of this teaching method on the students' achievements. Modern teaching theories consider an important effect of education on the development of students' affective domain, connected with the subject and its teaching. In this work, the author studies journal articles that use game-based learning in mathematics to assess its effects on the students, with the aim to analyze its impact on students' affective domain. To achieve this, a systematic review with the use of a PRISMA statement is applied. The data sources are 57 journal articles from the area of interest listed in the Web of Sciences and Scopus. The results indicate that 54% of the articles consider the affective domain in the measurement of the effects of game-based learning in mathematics education. These articles report mostly (84%) the positive influences of game-based learning on students' motivation, engagement, attitudes, enjoyment, state of flow, etc. The rest of the articles show mixed results, with the authors' conclusions possibly affected by flaws in the research instruments, selection of study groups, and game design, therefore, stressing the importance of these elements in future research on this topic.



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1. Introduction

Based on the fast progress of sciences and technologies, continuous innovations of the content, methods, and goals of school mathematics education are needed. One of the promising methods to achieve the active participation of students in learning activities and their higher motivation is game-based learning [1,2].

Game-based learning encourages active learning and engagement by providing students with possibilities to place problem-solving within the context of play [3].

The idea of games as an educational tool is not a new one, it was originally devised by Hellenic philosophers, Plato and Aristotle. In more recent history, game-based education has been part of the educational theories of important figures in this scientific area, such as J. A. Comenius (1592–1670), J. H. Pestalozzi (1746–1827), F. W. Fröbel (1782–1852), H. Spencer (1820–1903), K. Groos (1861–1946), M. Montessori (1870–1952), J. Piaget (1896–1980), L. S. Vygotsky (1896–1934), and J. Dewey (1859–1952) [4].

The impetus for the vast integration of game-based learning nowadays is driven by other factors, including the inclusion of digital technologies in education. Digital games support learning by giving students an opportunity to develop knowledge and cognitive skills, to learn by problem-solving, and to experience situational learning [5,6].

With this huge increase in game-based learning applications come natural questions about their effects on students. Many studies and reviews of existing research in this area have been conducted, mostly focused on the effect of games on students' performance compared with that of traditional classroom instruction [7].

Randel et al. [8], in their review, compared the effect on student's performance of games with that of traditional teaching in 68 studies up to 1991. The results were mixed;

the beneficial effects of games were mostly found when specific content was targeted. The review study of Hays [9], including 105 instructional gaming articles, also reported that the use of games in specific areas can provide effective learning, but the general conclusion was that there is no evidence that games are a preferred instructional method in all situations.

In the area of mathematics, educational games were identified as suitable to promote mathematic achievements in various domains, e.g., problem-solving and algebra skills [10], strategic and reasoning abilities [11], geometry skills [12], arithmetic [13,14], and critical thinking [15]. These studies are mostly focused on game-based learning's influences on mathematical achievements in the form of knowledge. But other important parts of mathematic education are affective factors such as students' motivation, beliefs, and attitudes towards mathematics and its teaching, as these factors can have a big impact on students' mathematical skills and their future mathematic learning [16–18]. Therefore, the question arises of how and to what extent game-based learning in mathematics education influences students' affectional dimension.

This question has already been discussed in some studies and reviews. The research of Garris et al. [19] found out that games could improve the engagement of students, advocating that games could influence outcomes including attitudes. These games were used in the setting of school education, but also in adult training. The study of Vogel et al. [20] reported positive effects of games vs. traditional teaching methods for both cognitive gains and attitude. However, the authors of the study considered the reliability to be low. The study of Ke and Grabowski [21] dealt with the effect of game-based learning on fifth-grade students' mathematics performance and attitudes. The results indicated that the integration of games positively influenced attitudes towards mathematics, mostly in cooperative structured groups. Based on a review of previous research studies, Vandercruysse [22] suggests that educational games positively affect students' attitudes, though just three journal articles support this suggestion.

The above-mentioned studies imply possible influences of game-based learning on students' affective factors connected with mathematics and its teaching process. However, these indications are fragmented and do not give a general overview of the influences of game-based learning on students' mathematics. Therefore, there is a need for a systematic review of the journal papers dealing with game-based learning in mathematics, focusing on the present state of research on the influences of game-based learning upon student's affective domain.

Based on this need, in the current paper, the following questions are investigated:

Q1: To what extent do the research studies dealing with the effects of game-based learning in the field of mathematics education address the influence of this teaching method on students' affective domain, connected with mathematics and its teaching?

Q2: Which journals have published scientific articles in this field?

Q3: What have been the influences of game-based learning on students' affective domain?

Q4: What research instruments were used to measure the influences of game-based learning on the affective factors?

To present answers to the research questions, the paper has the following structure. The next chapter details the materials and methods used for this systematic review. The third chapter states the result of the systematic review concerning the research questions. The last chapter discusses the results, comparing them with the outcomes of other studies, summarizes the limitations of the study, and proposes ideas for future research on this topic.

2. Materials and Methods

To answer the research questions, a systematic review was selected as the most appropriate research method, as it was developed for identifying and synthesizing research evidence by taking a systematic approach, following transparent and rigorous processes [23]. As the protocol for this systematic review, the author used the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) framework [24]. The reason behind the choice of PRISMA over other existing protocols was its comprehensiveness, its use in

several disciplines worldwide beyond the medical field for which it was originally developed, and its capability to increase consistency across reviews. The PRISMA checklist used in this paper reflects the fact that it is a systematic review, not a meta-analysis. Therefore, checklist items 12–16 and 19–23 were not included [24] (p. 3). This is in accordance with the recommendations on PRISMA applications for systematic review studies [25].

The eligibility criteria for the papers included in this systematic review are specified in Table 1.

Table 1. The criteria for eligibility.

Criterion	Inclusion	Exclusion
Document type	Published journal article (both empirical and review)	Book, book chapter, conference presentation, or other type of non-peer-reviewed or unpublished publication
Language	English	Articles not written in English
Accessibility	Open-access version of the article	Source with no open-access version available

According to the criteria, only published versions of journal articles are selected. This means that books, chapters in books, conference proceedings, etc., are excluded. This particular criterion is based on the higher scientific validity of peer-reviewed published journal articles when compared with other types of reports. For the journal articles, both empirical data articles and review articles are included, to cover the biggest possible range of data. The second selection criterion is the language; journal articles are accepted that are written in English. This is to avoid any confusion due to problems with translation and misunderstanding. The third inclusion criterion is that the open-access version of the article is used, to enable the extraction of all relevant data during the data collection process. The timeframe of selected articles is not limited, again, to achieve the biggest collection of relevant sources.

As information sources for this systematic review study, the author selected two major databases, namely Scopus and Web of Science. This selection was based on the broad range of the themes and journals covered in these databases, and their high scientific recognition. The items in these databases are systematically structured and search algorithms are provided that offer the possibility of covering all three eligibility criteria.

The search of the selected databases was implemented on 16 March 2021. The search terms were ‘game-based learning’ or ‘games’ combined with a Boolean operator AND with the terms ‘mathematics’ or ‘math’. The exact search strings and limits used are listed in Table 2.

Table 2. The search strings and limits used for the electronic search process.

Database	Search String and Limits
Scopus	TITLE ((“game” OR “game-based”) AND (“mathematics” OR “math”)) AND (LIMIT-TO (PUBSTAGE, “final”)) AND (LIMIT-TO (OA, “all”)) AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (SRCTYPE, “j”))
Web of Science	TI = ((“game” OR “game-based”) AND (“mathematics” OR “math”)) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article) Refined by: Open Access: (OPEN ACCESS) Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.

3. Results

The initial search highlighted 68 document results in the Scopus database and 37 results in the Web of Science database. The search results including the abstracts were exported for further screening in MS Excel. The next stage was the identification of duplicates, which led the author to find 20 duplicate records; those were excluded. The remaining records' abstracts were carefully studied to judge their relevance. A total of 27 articles were excluded as they did not focus on the effects of game-based learning in mathematics education. The remaining 58 papers were retrieved in the full text form. They were screened to further inspect their relevance. During this process, one paper was excluded since it was only partially written in English. This process left 57 articles; those are included in the qualitative synthesis described in the next part of the paper. A graphical representation of the flow of citations reviewed during the systematic review process is presented in Figure 1.

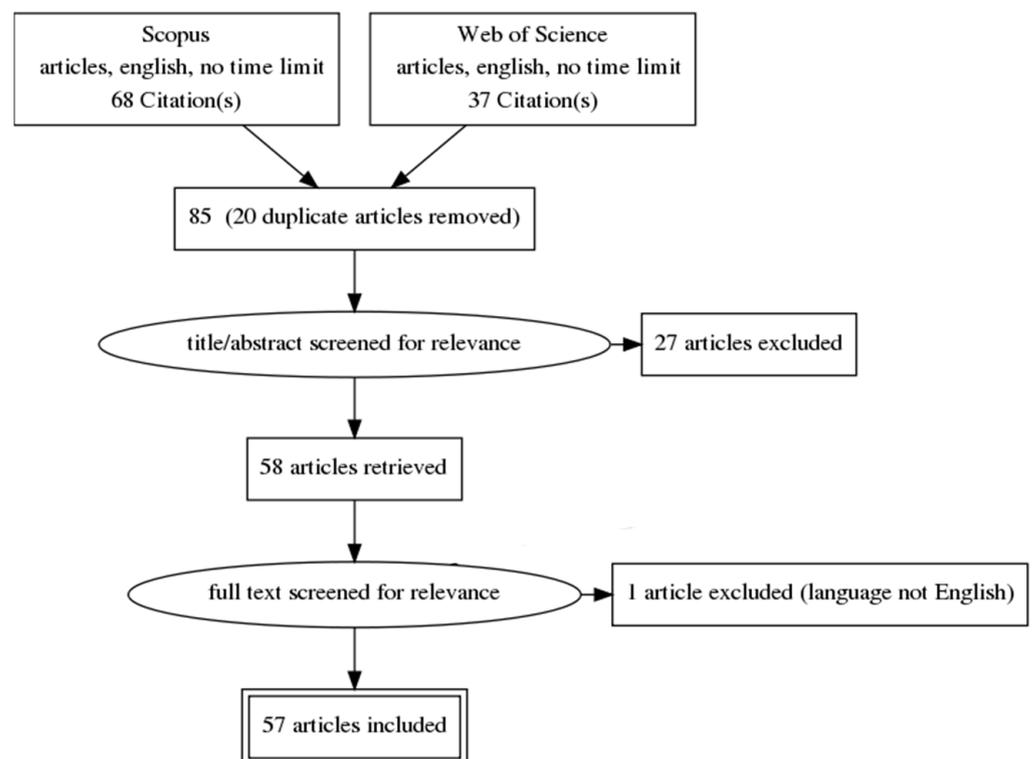


Figure 1. Systematic review flow diagram. Generated by PRISMA Flow Diagram Generator. Available online: <http://prisma.thetacollaborative.ca/> (accessed on 20 March 2021).

The 57 included articles were thoroughly studied to identify the results connected with the research questions of this paper. For this analysis, the software ATLAS.ti 9 was used, mainly because it enabled the analyst to solve a range of methodological challenges, such as working with large datasets and supporting deeper levels of analysis than are possible by hand [26]. During analysis, the author found that 26 articles [27–52] did not discuss the direct effects of game-based learning on the affective domain. So, to answer research questions Q2–Q4, the 31 remaining studies are investigated [6,53–82]. Table 3 summarizes the main characteristics of these game-based learning studies, with detailed information concerning the research questions.

Table 3. Study characteristics.

Ref.	Journal	Influence on MRAF ¹ [Positive/Negative/Mixed]	Measured Aspects of Affective Domain	Instruments to Measure MRAF ¹
[53]	Aust. J. Teach. Educ.	positive	motivation, engagement, state of flow, self-efficacy	questionnaire, video data
[54]	Aust. J. Teach. Educ.	positive	motivation, attitudes	interview
[55]	Br J Educ Technol	positive	motivation, attitudes	questionnaire
[56]	Br. J. Educ. Technol.	positive	motivation, engagement	observations
[57]	Education Tech. Research Dev.	mixed	motivation	questionnaire
[58]	EJEL	positive	attitudes	questionnaire
[59]	Eurasia J. Math. Sci. Technol. Educ.	mixed	attitudes, anxiety	questionnaire
[60]	Eurasia J. Math. Sci. Technol. Educ.	positive	motivation	unspecified
[61]	IEEE Access	positive	motivation, engagement, attitudes	questionnaire
[62]	iJOE	positive	motivation	literature review
[63]	IJSG	positive	motivation	video data
[64]	Informatics Educ.	positive	motivation, engagement, enjoyment	questionnaire, interview
[65]	Int. J. Artif. Intell. Educ.	positive	motivation	unspecified
[66]	Int. J. Multimedia Ubiquitous Eng.	positive	motivation	literature review
[67]	Int. J. Technol. Enhanc. Learn.	positive	state of flow	questionnaire
[68]	J Educ Psychol	positive	motivation, engagement, attitudes	questionnaire
[69]	J Educ Techno Soc	positive	self-efficacy, state of flow	questionnaire
[70]	J Math Didakt	positive	motivation, engagement	video data
[71]	J. Comput. Educ.	positive	motivation, self-efficacy, attention	questionnaire
[72]	J. Educ. E-Learn. Res.	mixed	attitudes	questionnaire
[73]	J. Educ. Techno. Soc.	positive	motivation, enjoyment, engagement	questionnaire, active participation
[74]	J. Inf. Organ. Sci.	positive	motivation, attitudes	literature review
[75]	J. Math. Educ.	positive	attitudes	questionnaire
[6]	Math. Ed. Res. J.	mixed	attitudes	questionnaire, interview, game data
[76]	MJLI	mixed	motivation	video data
[77]	MJLI	positive	motivation	unspecified
[78]	Rev. Colomb. Comput.	positive	motivation	questionnaire
[79]	Simul. Gaming	positive	motivation	active participation
[80]	Technol. Knowl. Learn.	positive	enjoyment	game data
[81]	Technologies	positive	engagement, enjoyment	questionnaire
[82]	Univers. J. Educ. Res.	positive	motivation	questionnaire

¹ Mathematics-related affective factors.

3.1. Extent of the Studies Considering the Affective Domain

As mentioned previously, of the 57 studies included in this systematic review, 31 (54%) addressed the affective domain in game-based learning in mathematics education, while 26 (46%) did not study the influences of game-based learning on the affective domain. The papers dealing with the affective domain were mostly from the last decade, and their number has slowly increasing trend, as can be seen in Figure 2.

3.2. Journals Publishing Studies Considering the Affective Domain

The 31 identified studies with research directly targeting the affective domain were published in scientific journals. Four journals (15%) contained two studies, while the remaining 23 journals (85%) included a single study. The scientific orientation of these journals was mostly Education and Educational Research, followed by Computer Science Interdisciplinary Applications, Psychology and Educational Sciences, and other similar scientific disciplines.

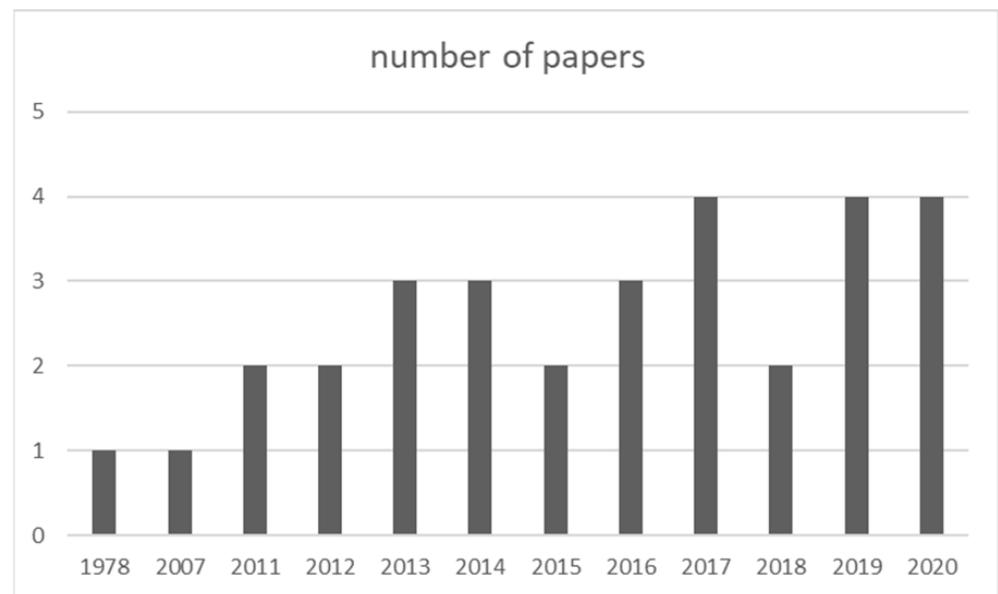


Figure 2. Publishing years of the source studies concerning the affective domain.

3.3. Influences of Game-Based Learning on the Affective Domain

The majority (26, i.e., 84%) of the journal articles dealing with the affective domain reported positive influences of game-based learning on students. These positive results related to the students' motivation (20 studies), engagement (eight studies), attitudes (seven studies), enjoyment (four studies), state of flow (three studies), and attention (one study). As for the number per study, one study reported four of the above-mentioned affective domain elements with positive results due to game-based learning, five studies reported three elements, seven studies considered two elements, and the remaining 13 studies focused on just one element of the affective domain.

The remaining five (16%) journal articles stated mixed results of game-based learning in mathematics education on students' affective domain. These results related to attitudes (three studies), motivation (two studies), and anxiety (one study). Of these studies with mixed results, one study addressed two elements of the affective domain and four studies just one element.

3.4. Instruments Used to Measure the Influences of Game-Based Learning on the Affective Domain

The most widely used research tool to study the influences of game-based learning on students' affective domain in mathematics education was a questionnaire, used in 18 studies (58%). The next most often used instrument was the analysis of video data (four studies), followed by an interview with the game participants (three studies), analysis of the data and metadata from the game (two studies), analysis of students' participation during game-based activities (two studies), and observation of students learning processes (one study). Three studies included literature reviews and three studies did not specify their research instruments.

Considering the number of instruments per study, one study used three of the above-mentioned instruments, three studies use two instruments, and the remaining studies used just one instrument or did not specify the instruments used.

4. Discussion

This systematic review concerns the influences of game-based learning on the affective domain, as studied in 54% of the journal articles in the area of game-based learning in mathematics education. These articles are mostly from the last decade and there is a slowly increasing trend of their number per year. The articles are published in various scientific journals with a broad scientific scope. This underlines that researchers in this

field understand the importance of the affective domain for effective teaching, as many include this important dimension in their studies. There is a trend of increasing research focused on the affective domain [16–18].

Considering the research instruments, the author found that the studies included mainly questionnaires (58%), interviews (12%), and analysis of video data (10%), or a combination of these instruments, which are standard in the assessment of the affective domain. This finding follows a general trend in research on this topic [83].

One very promising result of this review is the fact that the majority (84%) of the studied journal articles report positive effects of game-based learning on students' affective domain. These results mostly include increases in motivation and engagement, and improvements in students' attitudes related to mathematical content and its teaching. Although some of the articles report mixed results, none report a negative impact. The positive influences of game-based learning on the affective domain are in accordance with previous research in this area [19–22].

Those with mixed results note that playing the selected game did not have a discernible effect on students' motivation to learn math [57]. The authors conclude that this is because they incorporated into the game features that they believed would be entertaining, but that proved not to be the case for students. Alternatively, the questionnaire was not appropriately framed to allow the researchers to detect any effects on motivation. Another study [59] reports that in terms of learning anxiety, significant differences between students in the high-score and low-score groups may be a result of family factors, as most of the students in the high-score group were very familiar with computer operations, compared with students in the low-score group who had limited experience using computers. The other study with mixed results [72] shows that the use of mathematical games in math courses does not change students' attitudes towards mathematics courses in terms of the content that they are learning. However, in contrast, it was observed that students were much more active and had fun when learning; in addition, informal interviews with students showed that students had positive feelings and thoughts about their mathematics lessons. The authors conclude that this conflict in the results occurs since primary school students who are still in the concrete process period may not be able to fully internalize the scale items in the questionnaire used in the research. The article [76] states, as a reason for the mixed results, different play preferences and motivation, based on the content of the game and to what extent it motivates students and matches their preferences.

The limitations of this study concern the focus on journal articles, thus omitting other sources as books, book chapters, and conference papers. Moreover, this study focuses only on articles written in English. The author was also not able to include articles that were not open-access, which again limits the sample. However, the included databases Scopus and Web of Science are highly representative, and English is used in most of the scientific journals, therefore, these limitations should not influence the overall comprehensive nature of the study.

In conclusion, this systematic review indicates mostly positive influences of game-based learning on students' affective domain (84% of studies). Studies with mixed results, according to their authors, are mostly influenced by inappropriate research instruments, mistakes with the game design, or special conditions within the study groups. Based on this, the author can conclude that if those limiting factors are not present, then it is likely that positive influences of game-based learning will be recorded on students' affective domain. Therefore, proper research instruments, selection of study groups, and game design are recommended for future research on the topic of the influences of game-based learning.

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