Journal of Educational Technology & Online Learning
Volume 4 | Issue 2 | 2021
http://dergipark.org.tr/jetol

JETOL
JOURNAL OF EDUCATIONAL TECHNOLOGY & ONLINE LEARNING

An exploratory holistic analysis of digital gamification in mathematics education

Katibe Gizem Yığ[a], Sezan Sezgin[b*]

[a] Burdur Mehmet Akif Ersoy University, Turkey.
[b] Burdur Mehmet Akif Ersoy University, Turkey.

Suggested citation: Yığ, K. G. & Sezgin, S. (2021). An exploratory holistic analysis of digital gamification in mathematics education. *Journal of Educational Technology & Online Learning, 4*(2), 115-136.

Article Info

Keywords:

Digital gamification
Gamification in mathematics education
Social network analysis
Lexical analysis

Research Article

Abstract

This paper presents an explorative holistic analysis of digitally-constructed gamification processes in mathematics education. The main aim of this study is to identify the key-issues, intentions and trends by examining peer-reviewed publications using a combination of social network analysis (SNA), computerized lexical analysis and content analysis. Research findings indicate that there is a growing trend in gamification in mathematics education (GIME) research. GIME is mostly employed in primary school level. It was also found that, numbers is the most gamified math topic. Another research finding reveals that the researchers mostly use gamification to improve mathematical problem-solving, math achievement and math performance apart from the motivation and engagement. According to SNA findings, the most strategic terms in GIME research are as follows; geometry, fractions, mobile-learning, gender-studies, human-computer interaction, intelligent tutoring systems and tangible user-interfaces. GIME research is mostly influenced by USA and Brazil hence, the developing countries have an increasing interest in GIME research. Finally, findings on general research discourse implies that the general discourse among the sampled papers is positive. The findings obtained in this study may be useful to improve mathematics education by mapping a research agenda for researchers and educators with the exploration of potentials of GIME research.

1. Introduction

One of the general and accepted definitions of gamification is that, it is the use of game designs elements in non-game contexts (Deterding, Sicart, Nacke, O'Hara, & Dixon, 2011). Therefore, game-design elements are used to support individuals' daily actions and acts from different points (Huotari & Hamari, 2017). Thus, playful experiences can be provided for learning (Koivisto & Hamari, 2014). Hence, in order to understand and sympathize gamification with many educational concepts such as entertainment, problem solving, strategy development, and socialization, it must be recognized primarily that playing is a "basic learning instinct" for homosapiens (Huizinga 1955). The concept of gamification of learning-teaching, which basically includes the act of playing, was first coined by game designer Nick Pelling in 2002 (Werbach & Hunter, 2012) and took its place in Gartner Hype Cycle in 2011. However, we can evaluate the history of gamification together with the history of the games that the inclusion of games in daily life is as old as the history of humanity.

*Corresponding author : Department of Computer Education and Instructional Technologies, Burdur Mehmet Akif Ersoy University, Turkey
E-mail adresses: kgizemyig@mehmetakif.edu.tr, sezansezgin@mehmetakif.edu.tr

Doi: http://doi.org/10.31681/jetol.888096
Received 28 Feb 2021; Revised 16 Apr 2021; Accepted 20 Apr 2021;
ISSN: 2618-6586 .

The gamification approach is mainly used to support individuals' learning through motivation and engagement (Kapp, 2012). Gamification does not intend to provide learning directly, but it has an impact on many other learning variables through motivation, and engagement. Also, it can be assumed that gamification, together with many variables mentioned in the literature and in this study, may also have an effect on right brain skills or soft skills (Elayyan, 2021) such as "critical thinking, coordinating with others, verbal communications, and time management". In this context, it can be stated that gamification supports learning through many channels. Structural components of gamification are game mechanics, game dynamics and aesthetics. These components become a learning design language within the gamification thinking philosophy. One of the outputs of this design language, especially in the subject of this study, is to create intriguingly cleverly designed experiences (Kim, 2011). Another outcome is to provide problem solving skills and engagement to a learning situation (Zichermann & Cunningham, 2011).

Gamification can be analogue or digital, nevertheless, gamification is often "thought about as a digital realm" (Marczewski, 2019). We use only generic "gamification" term instead of "digital gamification" through this paper. The first starting point of this research is the assumption that gamification is a very appropriate approach to mathematics education with its features and learning variables that it affects. However, gamification, which is a very generous approach in terms of the use of technology, can be expected to offer solutions to the difficulties or constraints encountered in the field of mathematics education. At this point, it will be useful to summarize the difficulties encountered in mathematics education.

Mathematics is an intellectual query system aimed at solving problems encountered in the fields of "quantity, structure, space and change", increasing the existing knowledge and finding the universal facts (Lameras & Moumoutzis, 2015). This system attempts to explain the balance and harmony in the background of every occurrence in nature or created by human hand. The assumption that "the language of the nature" is mathematics (Lakoff & Núñez, 2000), is a result of such a reasoning system. The word mathematics has its origin in the Greek word; "mathesis" and, the word mathesis means "learning". In general, mathematics can be described as a tool with its own rules, processes and symbols used to explain the relationships existing in nature and to solve the problems encountered, and sometimes to pose a new problem. The interdisciplinary and central position of mathematics in many fields of knowledge such as education, technology is about the strong relationship between mathematics and pedagogy, its utilitarian nature and the nature of its subjects (i.e., quantity, structure, space and change) (Lameras & Moumoutzis, 2015). Therefore, it can be said that mathematics is the basic learning subject that people must internalize in the process of understanding and changing the world and providing benefits to others. Hence, the development of mathematics education for the individual and society is also a component of social development and progress. Mathematics should activate the mathematical thinking of individuals through proper examples which are consistent with their knowledge and skills. It should address their discovery sense and make them to ask questions about the effects of mathematics on daily life.

Although the term "school mathematics" differs from one country to another, it mainly deals with the learning domains such as numbers, algebra, geometry, measurement, data analysis (statistics) and probability (MONE, 2018; NCTM, 2000). Research suggests that the reasons for learning difficulties encountered in the field of mathematics are; the deficiencies in mathematics teaching, the abstractness of mathematics topics, the inability of the students to interpret the verbal expressions and the inadequate learning readiness levels of the students. In addition, studies on the efforts to eliminate difficulties are less frequent compared to studies on the identification of such difficulties. In the former type of the studies, it has been stated that computer programs for eliminating difficulties, visualization, using appropriate materials and redesigning teaching can be employed in line with learning difficulties (Tatar & Dikici, 2008).

Under the circumstances indicated above, it is clear that, nowadays, there is a need for the implementation of innovative approaches in teaching and learning of mathematics to eliminate the ongoing difficulties. Also, it can be claimed that, the long-used traditional in class teaching and learning methods in mathematics teaching are insufficient now to meet the needs of the new generation of learners. In this context, the aim of this study is to provide a systematical overview of the gamification in mathematics education (GIME) research by identifying trends and patterns through a systematic review of the related literature. In line with this aim this study addresses the following research questions.

- Is there a growth tendency in the number of studies published about GIME?
- What is the most used publication type among the sampled papers?
- What are the most used independent variables in GIME research?
- What are the characteristics of the target participants/samples in the related research?
- What are the most researched mathematical domains/topics?
- What are the trends in research design (or models) in studies on GIME research?
- Which keywords have the highest betweenness centrality and degree centrality?
- What is the countrywide distribution of related research?
- What is the general research discourse among the studies?
- What are the trends in GIME research in terms of lexical analysis?

2. Methodology

2.1. Research Model/Design

This paper is a hermeneutically-oriented (Boell & Cecez-Kecmanovic, 2014; Watson & Webster, 2020) explorative systematic review that seeks to arrive a holistic overview of digital gamification approach in mathematics education. The main aim to choose this type of research method was to identify the current state of the art, intentions and patterns of GIME research to guide researchers in future work (Petticrew & Roberts, 2008). Systematic reviews aim to summarize and thus, syntheses the results of previous studies in a specific field. This type of research seeks to inform the readers on the effectiveness of particular programs, approaches or methods by analyzing larger amounts of empirical studies that focus on the similar research topic (Van Klaveren & De Wolf, 2015). Setting predefined questions and inclusion & exclusion criterias are the typical prerequisites for systematic reviews. Systematic reviews can be regarded as “small scaled independent research projects in itself” (Denyer & Tranfield, 2009) that lead and direct trends for planning future breakthroughs.

For the purposes of this current systematic review, social network analysis (SNA), lexical thematic analysis, inferential descriptive statistics and discourse analysis were used to answer the research questions. Triangulation of analysis techniques used in this study helped authors to gain a multidimensional perspective and increase the validity of the research. A set of softwares were used in this study as follows: NodeXL (SNA-network visualization and computing centrality metrics), VOSviewer (Lexical analysis), Microsoft Word & Excel (descriptive and content analysis).

2.2. Sample and Inclusion Criteria

In this systematic review, to screen the peer reviewed papers, the Scopus database was used. Before conducting the screening process, authors also checked the other scientific databases such as Web of Science, ERIC, Science Direct and Google Scholar with predefined search keywords. Authors recorded the search results and formed a research inventory to Excel to check the search results between the selected databases. However, it was identified that the Scopus database provided the most comprehensive results between them.

The following search query of keywords were used to select the congruent articles for the research focus: “math OR mathematics AND gamification”. This query was searched in “abstract, title or keywords” sections of related papers. The search was not limited to a specific time period however the year 2020 was not included to research corpus to accurately map out the possible research trends. Initially, the searched papers were not limited to specific gamification modes as analogue or digital for not narrowing down the scope. Hence, surprisingly, researchers noticed that all sampled papers were digital gamification studies. The initial inclusion criteria for a research to be included to the scope of review are as follows: has predefined keywords in abstract, title or keywords, is peer reviewed, is written in English, has online full-text accessibility. The following criteria were used to exclude the studies from the scope of review: papers which are not written in English, studies that were abstracts (one or two pages) or opinion papers, white papers, reflection papers etc. The overall research design is shown in Figure 1.

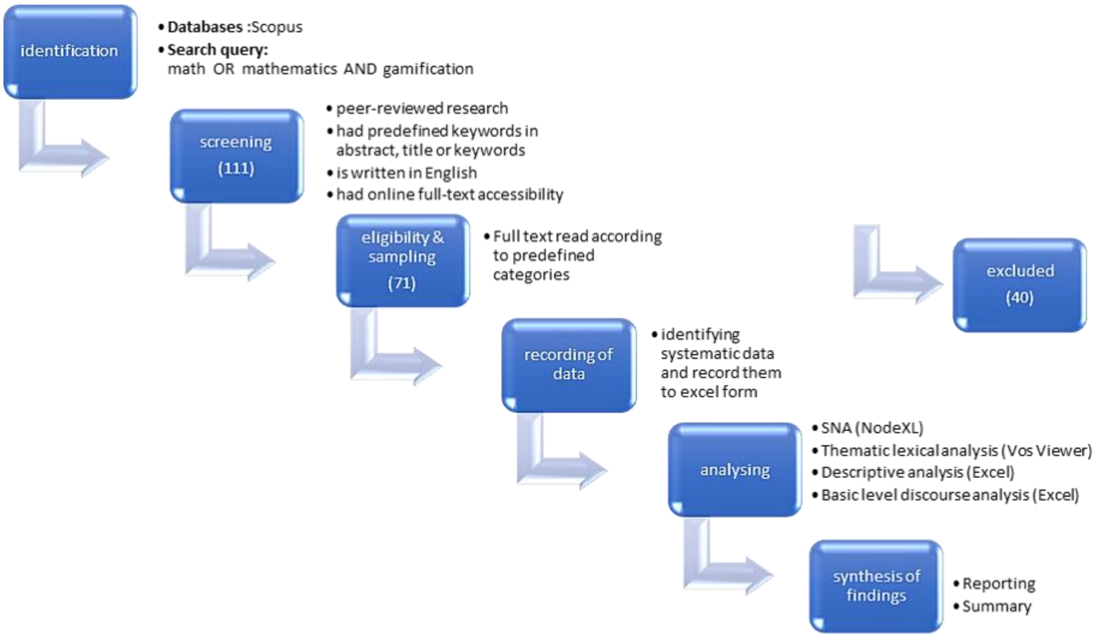


Fig. 1. The overall research design

2.3. Data collection and an analysis

After the initial screening process, we reached 111 papers. We then read all the paper abstracts, (and full texts where abstracts were unclear), to identify the papers relevant to our research focus. After removing duplicates, 40 papers were excluded and in the final research corpus, 71 peer reviewed papers were identified for the double review. After this screening phase, we read each papers’ full texts of the included articles in an attentive manner in line with the predefined systematic data categories. An Excel file, a NodeXL template and database metadata CSV files were used to record the data. In the Excel file, different data recording categories were defined by the authors namely; document type, year of study, country, keywords, participants, methodology, independent variables, dependent variables, math topic/domain and general research discourse. To arrive a comprehensive and reliable overview of GIME research and also to identify trends & patterns, this research benefits from multiple approaches to data analysis, as described below.

2.3.1. Descriptive analysis

In this systematic review, predefined systematic data categories; document type, year of study, country, participants, methodology, independent variables, dependent variables and math topic/domain were identified via descriptive statistics. Results of analysis were also presented with descriptive tables and a cartographic graph to clarify the results.

2.3.2. SNA based keyword network analysis

We used SNA, a conceptual data analysis method, to identify and map the relationships between the keywords used in sampled publications. SNA is a novel approach that analyses associational data within a network of actors (nodes), inter-related concepts or patterns (Crossley et al, 2015; Marin & Wellman, 2011). The philosophy behind SNA; decentralization in a network (Çulha, 2021), helps to uncover strategic knowledge/concepts within distributed information on a network. In this study, keywords were analyzed according to their co-occurrences. Hence, each keyword was identified as a node, while their co-occurrences were identified as ties. Understanding the effects and meanings of ties within a network of nodes (members) is the main focus of SNA. In this study, SNA conducted based on betweenness centrality (BC) metric and analysis of keyword network was visualized using the Harel Koren fast multiscale algorithm.

2.3.3. Lexical analysis

We used lexical thematic analysis to define core thematic codes among sampled publications. Lexical analysis is a statistical analysis of textual data (Hanks, 2013) which aims to explore and reveal the hidden topics in it. In this study, VOSviewer text-mining software, which constructs and visualizes bibliometric networks (Van Eck & Waltman, 2010) was used to create a thematic map of sampled publications' titles, abstracts and keywords. Thematic map was presented in the findings section.

2.3.4. Discourse analysis

Discourse analysis is a basic level content analysis that aims to identify the practical meaning of utterances (Johnstone, 2018). In this study, the conclusion sections (and also full texts where necessary) of sampled papers were analyzed in an attentive manner by the authors. Based on the discourse analysis carried out by Bozkurt, Akgün-Ozbek, & Zawacki-Richter (2017), the conclusion sections of the sampled papers were examined according to their concluding tones. Four clusters were defined to analyze the conclusion sections: "positive", "negative", "no significant effect" and "not applicable". General research discourse in a peer reviewed paper, is also a possible determinant of the effectiveness of gamification in mathematics education.

2.4. Reliability

To augment the reliability of this research, a double review process was implemented by the authors. In this type of systematic reviews, analyzing and recording data according to predefined systematic data categories properly, is a vital requirement. In line with this requirement, all sampled papers in this study were coded by two field experts respectively. Hence, Cohen Kappa statistic was used to determine the coefficient of interrater reliability. In Cohen Kappa statistic, a value of between 0.81 and 1.00 reflects almost perfect agreement between the coders. The interrater reliability coefficient was calculated as $\kappa = 0.915$ for descriptive parts of the analysis process. For the discourse analysis process, an interrater reliability coefficient was computed separately and found $\kappa = 0.980$, which indicates a perfect fit between the coders (Landis & Koch, 1977).

2.5. Significance of the Study

This study provides multiple perspectives of GIME research by identifying research tendencies, different patterns of usage and rising topics. The main aim of this current research was to examine the one of the most well fitted approaches to mathematics education, gamification, from different aspects. This examination may provide a holistic perspective to researchers, experts, teachers or teacher candidates. Also, to the best of our knowledge, this study is a unique research that attempts to identify the trends and possible direction of gamification usage in mathematics education. In other words, the study not only identifies specific patterns in GIME research, but also provides a prescient research agenda for future directions. Another strength of this study is the analyzing techniques used. These multiple techniques provide authors to triangulate the data to present more reliable synthesis and report.

In addition to its significance, this study has some limitations. First and foremost, the sampled papers are limited only to Scopus database. There may be a couple of significant publications in other databases but they may also be contributive to the current literature. In addition, however, Scopus is one of the largest and efficient databases in social sciences, it indexes only peer-reviewed documents such as articles, conference proceedings, and book chapters, thus grey literature such as expert blogs, project reports, positioning papers or white papers were not included to the research corpus. This may be count as a main limitation for this study.

3. Findings and discussion

3.1. Time Trend- Source/Research type

The studies reviewed were selected without any limitation in regard to the date of publication. However, it is observed that the studies on the GIME began from 2012. The gamification approach has its roots in the past, but the word gamification was first used officially in 2002 (Marczewski, 2013; Werbach & Hunter, 2012). However, by 2011, it officially became a buzzword when Gartner added it to its 'Hype Cycle' list. It can be argued that this situation increased the use and awareness of the gamification approach in different fields since 2011. When the time series is analyzed (Figure 2), it is observed that there is an increase in the studies on the GIME from 2012 to 2019. It is interesting that such studies on the GIME had the highest number in 2014 and had the peak point in 2018 even though Gartner (2014) positioned gamification at the “Trough of Disillusionment” stage.

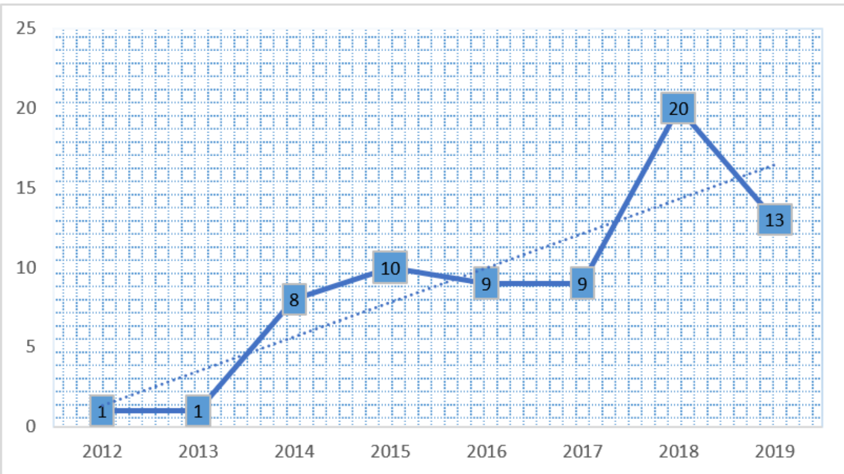


Fig. 2. Time trend series of GIME research

It can be thought that due to the assumption that gamification is an “effective learning-teaching approach” that appeals to the instincts of individuals in regard to games, and the that the role of technology in gamification practices is very significant such an increase occurred. It has been frequently observed in many systematic review studies that the cut-off dates related to the technological development or the introduction of new approaches also show the effect of those technologies or approaches in the educational processes as multi-disciplinary manner (Bozkurt, Akgün-Özbek, & Zawacki-Richter, 2017; Bozkurt & Göksel, 2018; de Sousa Borges, Durelli, Reis, & Isotani, 2014). Time trend analysis suggests that gamification is increasingly being studied in mathematics education starting with 2012 and moreover, it is subject to various experimental and practice-based studies, as stated in the "methods used" section in the sampled researches. On the other hand, out of seventy-one studies reviewed, fifty-one are articles (71,83 %) and twenty are conference papers (28,17 %).

3.2. Independent Variables Focused in the Studies

In the studies on GIME, when the potential effects of gamification independent variable on the dependent variables are analyzed, the variables of motivation, engagement, problem solving, math achievement and math performance become much more significant.

variables	n	f(%)	variables	n	f(%)
motivation	9	11,11	distraction	1	1,23
engagement	8	9,88	extrinct motivation	1	1,23
problem solving	7	8,64	interaction	1	1,23
maths achievement	6	7,41	interest	1	1,23
math performance	4	4,94	learning at higher levels	1	1,23
intrinsic motivation	3	3,70	learning styles	1	1,23
learning process	3	3,70	learning success	1	1,23
academic achievement	2	2,47	procedural knowledge	1	1,23
learning performance	2	2,47	process of studying mathematics	1	1,23
perfomance	2	2,47	response accuracy	1	1,23
student learning outcomes	2	2,47	response time	1	1,23
learners anxiety levels	2	2,47	self-regulation	1	1,23
autonomy	1	1,23	social participation	1	1,23
cognitive overload	1	1,23	spatial skills	1	1,23
collaboration	1	1,23	speed	1	1,23
communication	1	1,23	strategic efficiency	1	1,23
computational thinking	1	1,23	strategic fexibility	1	1,23
concentration	1	1,23	student achievement	1	1,23
conceptual knowledge	1	1,23	student attitudes	1	1,23
correctedness of entries	1	1,23	task completetion	1	1,23
creative abilities	1	1,23	test perfomance	1	1,23
			user involment to e-learning	1	1,23

Fig. 3. Independent variables in the sampled publications

In many studies, it is stated that gamification approach is mainly effective on student motivation and engagement variables instead of direct learning performance (Deterding, 2012; Hamari, Koivisto, & Sarsa, 2014; Marczewski, 2013). One of the interesting findings obtained in this study is that gamification can be an effective independent variable especially in problem solving, mathematics achievement and performance in the field of mathematics education. However, although student motivation and engagement are the target variables of gamification, the fact that the researchers who integrate gamification into mathematics education especially include these two variables which indicates that these variables are also important-problem solving variables in mathematics education.

3.3. Population and/or Participant Groups

The categorization of students' education levels may differ by country. For this reason, in this study, which age group is referred to at which education level is clearly stated in Table 1. Participants outside these groups are categorized in the "other" category, and in this category, there are studies with individuals with special needs (n = 3), adult learners (n = 2) and teachers (n = 1). The frequency of the studies conducted of which participants are stated is given in Table 1.

Table 1.

Educational levels and grades of participants

Educational Level	Age	Grade	f
Preschool	4-5-6	Kindergarden	5
Primary School	7-8-9-10-11	1,2,3,4,5	24
Middle School	12-13-14	6,7,8	8
High School	15-16-17-18	9,10,11,12	9
Higher Education	18 +	Undergraduate	13
Other	-	-	6

When the education levels of the participants are examined in the studies dealing with gamification in mathematics teaching, it is seen that studies involving the participants who are at the primary school level are the most frequent. It is observed that the other studies were respectively carried out of with the participants from the higher education, high school, secondary school, others and pre-school level participants.

3.4. Math topics focused with regards to participants' grade

The subject area classification specified in the National Council of Teachers of Mathematics (NCTM) was used to classify the mathematics topics addressed in the gamification research. Distribution of subject areas by grade levels according to the NCTM standards is given in Figure 4 (NCTM, 2000). Accordingly, the subject domains covered in the field of mathematics from preschool to high school can be classified as numbers, algebra, geometry, measurement, data analysis and probability.

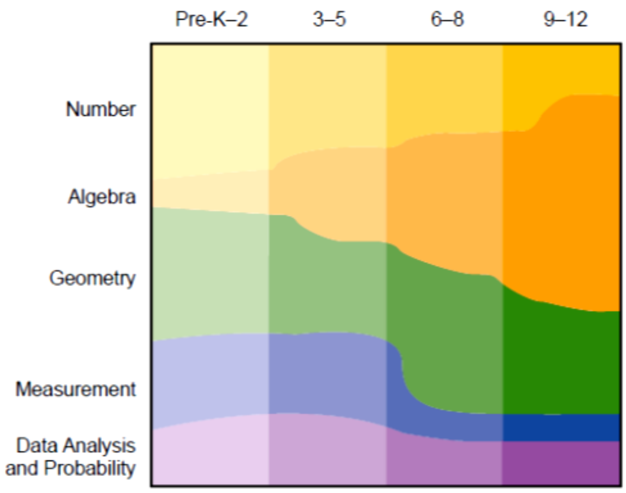


Fig. 4. Distribution of mathematics subject areas by grade levels according to the NCTM standards (NCTM, 2000, p.30)

In some of the sampled studies, the subject of mathematics courses was not specified, and in some of the cases, the subject area was not clearly defined and instead, was given unclear such as "math comprehension". These studies are marked as N / A. In some studies, cases/activities related to more than one subject area were found. These studies are coded to be more than one for each mathematics subject area. The findings regarding the distribution of gamification research according to education level and mathematics subject areas are summarized in Table 2.

Table 2.

Math domains of sampled papers with regards to educational level of learners

		Educational Level			
		Preschool (n=5)	Primary School (n=24)	Middle School (n=9)	High School (n=9)
Maths Domain	Number	2	13	3	1
	Algebra	-	3	-	2
	Geometry	-	2	2	2
	Measurement	-	-	-	-
	Data analysis and probability	-	1	-	-
	N/A	3	8	5	5

The findings in Table 2 indicate that when the subject areas of the studies are taken into consideration, it is seen that majority of the studies at pre-school level are on “numbers”. It is also seen that the gamification studies are carried out mostly on “numbers” (f = 13) at primary school level. Apart from eight studies in which the subject of mathematics could not be determined clearly, three studies including algebra field, one containing geometry field and one research involving data analysis and probability were carried out.

When the mathematics subjects of studies carried out at the middle school level were examined, it is observed that there were three studies on number and two studies on geometry. It was not possible to determine what the mathematics subject of five studies at middle school level. At the high school level, one study is found to address the number issue and two studies focus on the algebra and geometry areas. At the high school level, the subject of mathematics of five studies could not be determined.

Therefore, it is safe to argue that “numbers” seem to be the dominant research topic for the preschool level. It has been determined that the gamification studies carried out are also in this domain. At primary school level, it is seen that especially in 3-5 grade levels, the focus is on the “numbers and geometry” area, following this, on “algebra” and “measurement”, and less predominantly on the “data analysis” and “probability” domains (NCTM, 2000, p.30). Although the number of the studies on the topics of “numbers” and “geometry” are the same, it is seen that gamification research concentrates mostly on numbers.

In mathematics education, it is seen that the effects of gamification on students' motivation, attitudes, mathematical engagement and mathematical knowledge and skills are examined, and gamification is used in eliminating various mathematical difficulties (Cunha, Barraqui & De Freitas, 2018; Jagust, Boticki & So, 2018; Widodo & Rayahu, 2019; Toda, do Carmo, Mesquita, da Silva, & Brancher, 2014). Given that gamification studies are an approach to eliminate learning difficulties, the question of whether gamification research is focused on numbers mostly due to the fact that there is more difficulty in numbers occurs. However, it is also emphasized in studies conducted in different countries that geometry is one of the most challenged and unsuccessful subjects among the students (Aldolphus, 2011; Bartoni-Bussi & Baccaglini-Franck, 2015; Clements, Sarama, Swaminathan, Weber, & Trawick-Smith, 2018; Koçak & Soylu, 2018). Then it can be argued that the studies of gamification have not been focused on algebra yet, however, this literature inference sheds light on it and mean that such studies can be implemented.

Similarly, the frequent study topics for the middle school level (grades 6-8) is found to be algebra followed by the topics of geometry, numbers, data analysis and measurement. However, when the studies of which the subject area was specified, were examined, a gamification study focusing on the field of algebra was not found. It is a known fact that the subject of area of algebra is very difficult to understand from the perspectives of students, and it is a basic subject area for the high school level (Dubinsky & Wilson, 2013; Kaya & Keşan, 2014). Considering the importance of the subject of algebra, it can be said that there is a need for gamification studies to increase the motivation of learning in relation to algebra and to eliminate difficulties. Mathematics education at the high school level generally focuses on the algebra. Following this, the topics related to the fields of geometry and the trace of the numbers, the measurement and the data analysis (NCTM, 200, p. 30). It is seen that the subject areas that can be determined in the gamification research conducted at the high school level are dominantly in algebra and geometry, and then numbers.

Another remarkable finding is that any gamification study in the measurement area has not been reached. One of the reasons for this situation, although it varies according to the countries, is thought that the measurement subject in the education programs may have less significance and emphasis than other mathematics subject areas. It is thought that examining the reasons for not having the need to use gamification for increasing motivation and success in the field of measurement can contribute to the mathematics education field.

There are eleven studies determined to be carried out with participants who were at the higher education level. More specifically, it is seen that four studies focused on the analysis, two on the algebra, two on geometry, one focuses on discrete mathematic and another one focuses on statistics. The subject area of one study could not be determined. On the other hand, it is found that some studies include more than one subject area. In two studies, it was aimed to develop spatial skills which are part of the mathematical skills. Regardless of the education levels, there are five studies grouped in the “other” category. The subject area of mathematics in one study could not be identified. Some studies include more than one mathematical subject. Three studies include the topic of numbers, three studies dealt with the algebra topics, one study includes mathematical literacy, one study focuses on geometry, and one study focuses on logic.

3.5. Research methods used

When the methods of the sampled studies are examined, it is seen that the experimental studies are highly preferred (39, 44%). However, it is also observed that the majority of the studies do not have a specific method, but these studies can be described as practice-based research in general which is also preferred considerably (35, 21%).

Table 3.

Research methods / approaches used in the sampled publications (adapted from Bozkurt, Akgün-Ozbek, & Zawacki-Richter (2017))

Type	n	F	Type	n	f	Type	n	f
Quantitative	**29**	**40,85**	**Mixed**	**2**	**2,82**	**Practice based**	**25**	**35,21**
Survey	1	1,41	Explanatory sequential	1	1,41	Action research	0	0,00
Correlational	0	0,00	Convergent parallel	1	1,41	Design-based research	3	4,23
Experimental	28	39,44	Exploratory sequential	0	0,00	Game development	9	12,68
Meta-analysis	0	0,00	Embedded	0	0,00	System / Tool / Prototype development	7	9,86
Causal comparative	0	0,00	Multiphase	0	0,00	Instructional design development	3	4,23
			Transformative	0	0,00	application development	3	4,23
Qualitative	**6**	**8,45**	**Conceptual/Descriptive /Other**	**9**	**12,68**			
Descriptive	1	1,41	Literature review	2	2,82			
Case Study	4	5,63	Position paper	0	0,00			
Content Analysis	0	0,00	Opinion paper	0	0,00			
Ethnography	1	1,41	Report	1	1,41			
Phenomenology	0	0,00	Comparative	0	0,00			
Narrative	0	0,00	Technical paper	3	4,23			
Delphi	0	0,00	Reflection paper	1	1,41			
Grounded theory	0	0,00	Field notes	2	2,82			
Meta-Synthesis	0	0,00						

Historical	0	0,00
Heuristic	0	0,00

Among the practice-based researches, there are game development studies (12, 68%), system architecture creation / a learning-teaching tool or prototype development studies (9, 68%), teaching design development studies (4, 23%) mobile application development studies (4, 23%) and other design-based processes (4, 23%). The rate of conceptual-descriptive studies is 12, 68 %, and the qualitative research is the least preferred research method (8, 45%). It is not possible to evaluate these findings together with similar research results since there are no similar review of the GIME studies in the literature. However, findings obtained in systematic literature reviews related to gamification, or systematic reviews performed in different disciplines (Martí - Parreño, Méndez - Ibáñez, & Alonso - Arroyo, 2016; Ortiz Rojas, Chiluiza, & Valcke, 2016), are parallel to the findings of this research. Accordingly, gamification is an approach that mostly has been tested in experimental environments (39.44%) with its various effects on different learner groups. It can be said this situation is caused by genetic inheritance of gamification from games: Games are systems consisting of many components.

3.6. SNA based keyword network analysis

In order to better understand the research topics and trends in the studies reviewed, a SNA was carried out in with the keywords of sampled publications. The SNA is an analysis method that can make a meaningful summary of the relationships in a network by examining the actors in a social network and the connections between them. In addition, SNA is an approach that can be used in the analysis of relational data derived from an interdisciplinary network of related concepts, theories or techniques (Crossley et al, 2015). In the SNA process, each keyword was identified as a node, while their co-occurrences were identified as ties. NodeXL, a social network analysis software was used to analyse and visualize these nodes. A co-occurrence network was created among the nodes. The network graph created represents 178 nodes with 557 ties between them. Also, the nodes which have degrees under 4 were not shown on the network map to clarify the general visualization (Figure 5).

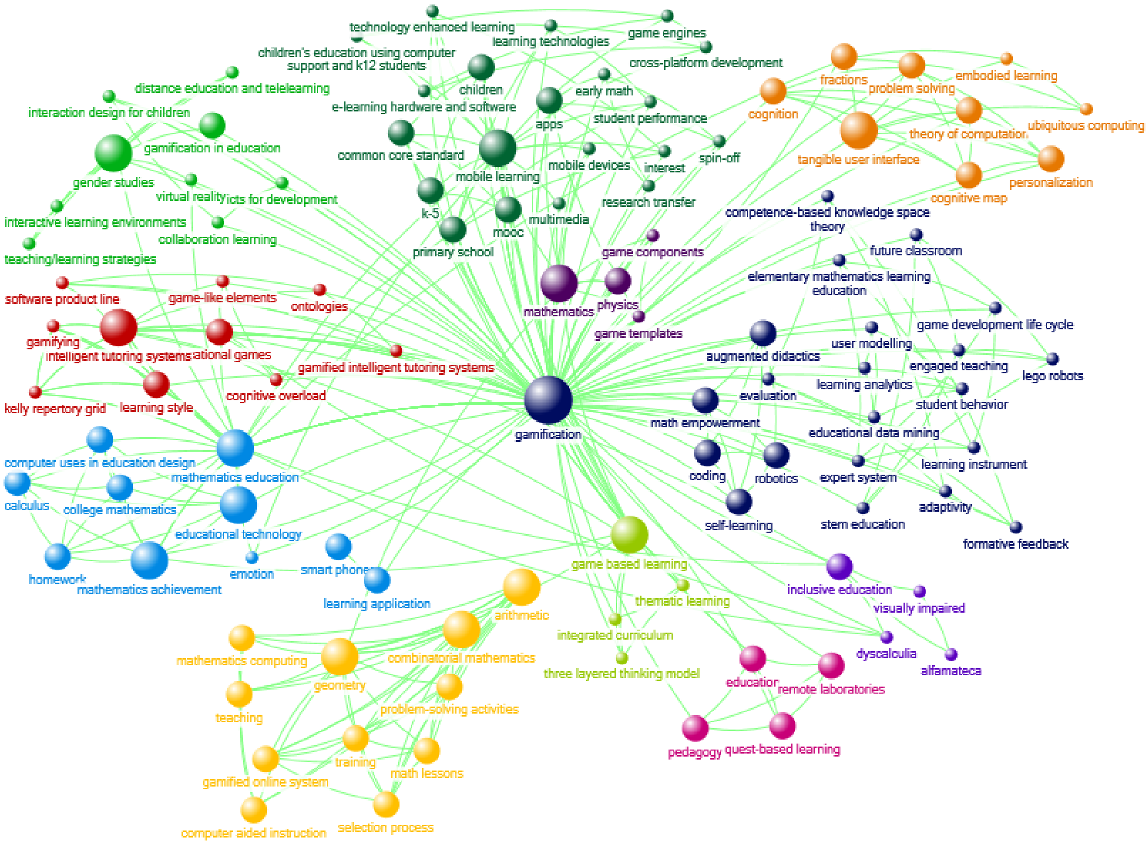


Fig. 5. Network graph of sampled keywords

Keywords were laid out using the Harel-Koren Fast layout algorithm and grouped by cluster using the Girman-Newman-Moore cluster algorithm. The analysis was based on betweenness centrality of nodes. Betweenness centrality metric in a SNA, is based on how important a node is, in terms of connecting to other nodes (Rusinowska, Berghammer, De Swart, & Grabisch, 2011). In other words, in a specific study of domain, betweenness centrality identifies the strategically important concepts/topics which controls the relationship among others or has ability to bridge over diversified topics.

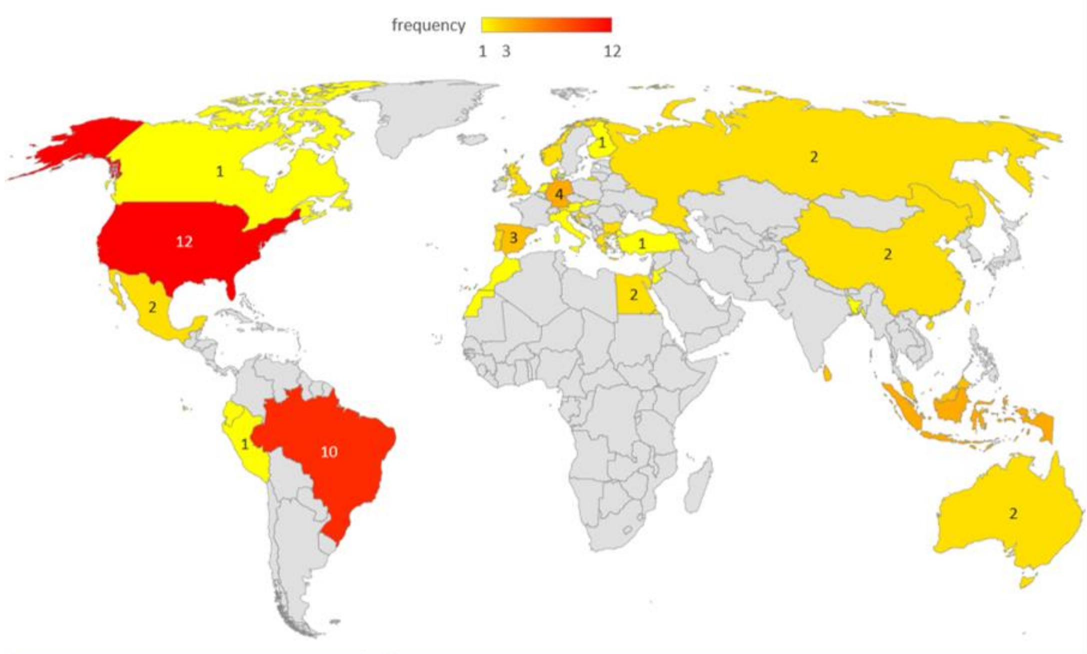
node	betwenness centrality	degree centrality	frequency
gamification	15095,8452	148	49
game-based-learning	2383,4000	18	6
mathematics-education	2081,2524	37	7
geometry	2006,9000	14	3
mobile-learning	1357,0143	24	6
gender-studies	891,0000	11	3
human-computer-interaction	812,0000	10	3
kahoot	760,0000	8	2
inclusive-education	744,0000	8	2
educational-technology	608,5000	9	2
fractions	403,7500	7	2
tangible-user-interfaces	387,7500	12	2
children-education	349,0000	4	4
mathematics	326,7333	15	5
gamification-in-education	224,5000	6	2
educational-games	201,6667	9	3
cross-platform development	151,3476	4	1
e-learning-hardware&software	151,3476	4	1
game-engines	151,3476	4	1
arithmetic	147,8333	12	2
learner-engagement	48,0000	15	2
intelligent-tutoring-systems	35,5000	17	8
mathematics-achievement	14,3333	11	3
combinatorial-mathematics	5,0000	11	2
e-learning	4,5000	10	3
education	3,0000	8	3
primary-school	1,3333	8	3
apps	1,2500	6	2
learning-style	0,66667	10	2
physics	0,66667	6	2

Fig. 6. The nodes with high betweenness centrality scores

Unsurprisingly, gamification emerges as the central node (Figure 5-6). Another strategic nodes are found to be game based learning, mathematics education, geometry, and mobile learning. As a result of the analysis, it is found as expected that the game-based learning as well as gamification has a high BC value. Gamification and game-based learning are two frequently confused approaches in the literature. Here, there may be a similar situation/confusion. One of the remarkable findings in the SNA is that geometry and mobile learning subjects stand out as mediators, together with mathematics education, among different special mathematics topics. In addition, in mathematics; gender research, human computer interaction, fractions, and tangible user interfaces are the important topics of GIME research. Intelligent tutoring systems is another GIME subject that is the most frequently used and relatively high BC in keyword analysis of the studies reviewed. This finding indicates that artificial intelligence-based ITS systems have become an important topic in mathematics education and the GIME research as in other fields.

3.7. Countrywide distribution

When the country distribution of the sampled publications is examined, it is seen that the USA (16.22%) and Brazil (13.52%) stand out in terms of the number of the GIME studies. Germany (5.41%) and Indonesia (5.41%) follow them. In general, it is seen that the USA leads the way in innovative mathematics teaching practices. Herein, the number of productions of Brazil, a developing country, in this area is another remarkable point to be examined.



United States	12	Greece	2	Egypt	2	Netherlands	1
Brasil	10	Norway	2	Mexico	2	Slovakia	1
Germany	4	Portugal	2	Russia	2	Bangladesh	1
Indonesia	4	Taiwan	2	Denmark	1	Jordan	1
Spain	3	UK	2	Austria	1	Morocco	1
Malaysia	3	Bulgaria	2	Canada	1	Peru	1
Sri Lanka	3	China	2	Finland	1	Turkey	1
Australia	2	Croatia	2	Italy	1	Ecuador	1

Fig. 7. Main contributors in GIME research

In similar studies, it is generally stated that the number of publications carried out in the developed countries is higher than that carried out in the developing countries. The interesting finding that emerged here; if we keep the data from the USA apart, it is observed that there are more GIME studies in the developing countries compared to the developed countries. Therefore, it is possible to argue that mathematics education is perceived as an important challenge that needs to be solved in the developing countries. In addition, it provides an indication that innovative approaches such as gamification, especially suitable for mathematics education, are tried to be integrated as an approach that can accelerate mathematics education by providing solutions to problems in mathematics education.

3.8. General research discourse- Does gamification work in mathematics education?

When the conclusion parts of the studies reviewed are examined in detail, gamification in mathematics education is often reported to be of high usefulness/beneficialness (Figure 8). Only seven studies do not report any effects (10%), and only one study (1%) did not show any significant effects of the gamification. In order to monitor the effects of the gamification approach in mathematics education more clearly, those learning variables which have positive effects on gamification should be investigated in future meta-analytic or experimental studies.

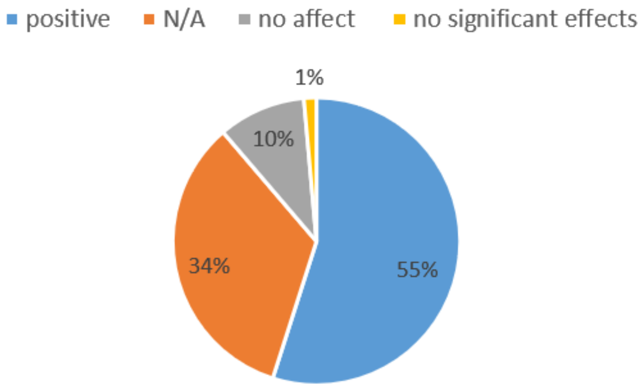


Fig. 8. General research discourse among the sampled publications

The findings of this study related to the general research discourse coincide with the findings of various systematic review studies on gamification in education. In the study of Dicheva, Dichev, Agre, & Angelova (2015) it is revealed that gamification has positive effects on education in the majority of the analyzed studies. Similarly, in the study of Ortiz Rojas et. al. (2016), it is stated that the number of studies reporting the negative effects of gamification in education is very low. Based on the general research discourse findings obtained in this study, it is concluded that gamification has a positive effect on mathematics education. Especially the studies in which there is no specific result are generally application-based. Considering that there are studies for developing a product and system, it can be said that the rate expressing the positive effects of using gamification in mathematics education will be higher than the rates given in Figure 8. As a result, the finding sheds light on the fact that the use of gamification in mathematics education may have important positive effects in terms of educational beneficialness.

3.9. Thematic /lexical-text mining analysis

Another analysis carried out within the scope of the study is text mining based computerized lexical analysis. The VOSviewer program was used for the analysis (Van Eck & Waltman, 2010), and the article data obtained from the Scopus database were analyzed at the level of summary and titles with full counting method. The VOSviewer has "text mining functionality that can be used to construct and visualize co-occurrence networks of important terms extracted from a body of scientific literature" (Van Eck & Waltman, 2010). The lexical analysis map produced in this study is presented in Figure 9.

In the analysis process, minimum number of occurrences of a term was determined as 9 (default value is 10) to clarify the visualization and the number of terms to be selected was automatically reported as 41. Analysis revealed 5 clusters and each cluster was visualized with different colors and ties. Accordingly, the terms; system, technology, activity, teacher, child, level, development, engagement and performance have the highest occurrence numbers hence, the terms; educational video game, leaderboard, question, time and control group have the highest relevance coefficients.

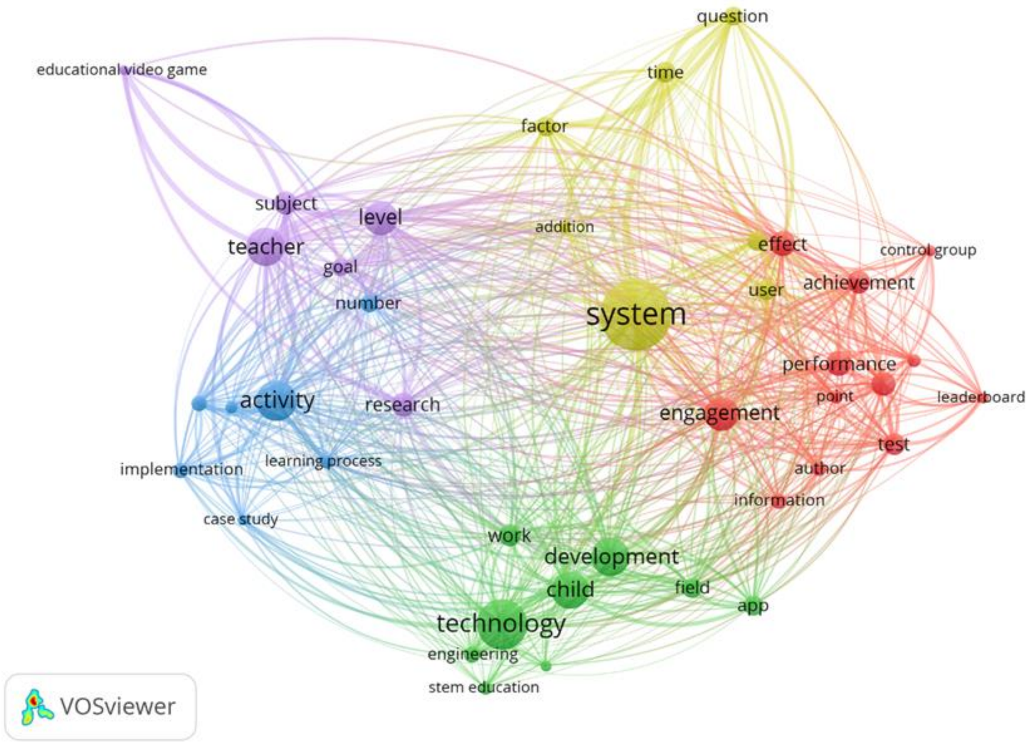


Fig. 9. Bibliometric map of sampled publications derived from lexical analysis

Figure 9 presents some intriguing results. Firstly, it was interesting to see that studies mostly focused on gamified or mathematical systems. These systems need to be created and tested experimentally. Thus, this finding supports the concluding arguments in "research methods" section of this paper. In addition, performance and engagement are the common variables in gamified experimental settings. This finding also supports the general research outcomes of gamification of learning. Accordingly, engagement and learner performance are the most investigated variables in gamification studies (Faiella & Ricciardi, 2015; Nah, Zeng, Telaprolu, Ayyappa, & Eschenbrenner, 2014; Ortiz Rojas, Chiluiza, & Valcke, 2016). Another finding of lexical analysis indicates that in GIME studies; leaderboards, points, achievements, levels and tests are said to be the most mentioned gamification components. Also, technology appears to be a common and standardized concept in GIME research.

4. Conclusion and future implications

In this paper, we conducted an explorative systematic analysis of peer-reviewed publications on gamification approach in mathematics education. The main aim of was to identify the trends, intentions and patterns of current body of GIME research literature. Key issues and trends in mathematics education with regards to gamification were identified through a triangulation of social network analysis, content analysis and lexical analysis (computerized text mining).

The findings of the study first, reveal an increasing trend towards the use of the gamification approach in mathematics education research. This situation can be interpreted as the recognition of the researchers in relation to the fact that gamification can be a very effective approach to enrich mathematics education. On the other hand, gamification can offer unique learning experiences to learners of all ages. This study has found that gamification is more studied especially in relation to the mathematics education at primary school level. It is followed by the levels of the undergraduate education and other educational levels. This situation can be attributed to the experiments aimed at eliminating the attention and motivation deficiencies experienced by the new generation learners, who are studying at primary school level. However, the results of this study reveal that gamification may be considered as an educational problem solver that can be used in mathematics education at various grade levels.

Another important result obtained in this study is related to the distribution of mathematics subject areas analyzed in GIME research. When these studies are analyzed in terms of mathematics subject areas, it is seen that the focus is mostly on teaching of numbers, and then, on geometry and algebra. When the mathematics subjects are examined in terms of education levels, it does not seem possible to talk about a general tendency regarding the weights of the subjects in the curriculum or the subjects that have difficulty in mathematics.

Within the scope of the study, the dependent variables in which GIME researches dealt with the possible effects of gamification independent variable were examined. Accordingly, as expected, the variables of student motivation and engagement, as well as the variables of problem solving, math achievement and math performance, have significance and dominant. It is known that gamification has mostly significant effects on student motivation and engagement. The descriptive data obtained in the study were also supported by discourse analysis. These findings also reveal that gamification can be used in the context of the above-mentioned variables in the field of mathematics, with a focus on student achievement and knowledge gain.

Another research finding suggests that the methods of the investigated studies were predominantly based on experimental methods. There are also some other studies that do not have a specific method, but that can be described as practice-based research in general. Accordingly, empirical observation of gamification in mathematics is carried out with the help of experimental research designs. This indicates that gamification is accepted by mathematical researchers in terms of its theoretical background. Another takeaway suggested by this research is that the systematic structure of gamification is compatible with the systematic structure of mathematics. In other words, the determination of the effectiveness of the systems can be easily supported with the help of quantitative methodology.

According to the results of the SNA carried out within the scope of the study, some strategic subject areas in the GIME research include the concepts such as geometry, mobile learning, gender research, human computer interaction (HCI), fractions, tangible user interfaces, intelligent tutoring systems (ITS). Each of these concepts actually reflects the trends in the GIME research, which are important topics that directed another research. The surprising result is that gender studies in mathematics education are still being studied, albeit with different approaches. This may also be caused by the difference in motivation of individuals of different genders in regard to games. Another remarkable result within the scope of the SNA is the fact that geometry and fractions are prominent in the GIME research area as field specific. In addition, its emergence as an important concept in tangible user interfaces explains that the use of manipulative and models is taken into account in mathematics teaching. The concepts of HCI and ITS are also important conceptual findings that point to the future direction of GIME research.

Within the scope of the study, influencer countries were examined in terms of the GIME researches. Although USA and Brazil are at the forefront, when the USA is kept separate, it has been determined that more GIME studies are carried out in the developing countries. Good economic conditions can be achieved with good mathematicians. In this context, innovative approaches such as gamification in mathematics education will enrich mathematics education and may provide solutions to some basic education problems especially in the developing countries. Therefore, it can be thought that the developing countries mentioned in the research are on the right path by giving importance to the GIME researches.

Discourse analysis of the studies examined within the scope of the study shows that the use of gamification in mathematics education has positive effects. In other words, it was concluded that gamification "works" in mathematics education. However, it seems that the use of gamification and technology together in mathematics education is also important.

One of the important features of gamification is that the success of gamification is highly context based (Hamari, Koivisto, & Sarsa, 2014). In other words, different gamification thoughts can be realized in different fields or subjects. Based on the results of the research, the following recommendations can be given for researchers, teachers, prospective teachers or experts working in the field of mathematics education:

- As stated above, gamification is a highly context-based approach. At this point, researchers should know the context to be gamified well, moreover, they should have sufficient TPACK skills.
- Gamification is an approach that has different components and requires design experience and creativity. However, the educational power of the games is quite high. From this point of view, increasing gamification education and gamified content may cause positive effects in mathematics education as in other disciplines. However, at this point, subjects such as motivation, attention, engagement, etc. that affect students' learning of mathematics should be determined. In this way, more effective solutions can be offered for the mathematics subjects, which are difficult to teach, through gamification.
- Supporting GIME researches with qualitative data collection and analysis methods in addition to experimental designs will provide researchers with deeper insights.

References

Adolphus, T. (2011). Problems of teaching and learning of geometry in secondary schools in Rivers State, Nigeria. *International Journal of Emerging Sciences*, *1*(2), 143-152. https://dspace.stir.ac.uk/bitstream/1893/26189/1/Problems_of_Teaching_and_Learning_of_Geo.pdf

Bartolini Bussi, M. G., & Baccaglini-Frank, A. (2015). Geometry in early years: sowing seeds for a mathematical definition of squares and rectangles. *ZDM*, *47*(3), 391-405. https://doi.org/10.1007/s11858-014-0636-5

Boell, S. K., & Cecez-Kecmanovic, D. (2014). A hermeneutic approach for conducting literature reviews and literature searches. *Communications of the association for information systems*, *34*(1), 12. https://doi.org/10.17705/1CAIS.03412

Bozkurt, A., Akgün-Özbek, E., & Zawacki-Richter, O. (2017). Trends and patterns in massive open online courses: Review and content analysis of research on MOOCs (2008-2015). *International Review of Research in Open and Distributed Learning: IRRODL*, *18*(5), 118-147. https://doi.org/10.19173/irrodl.v18i5.3080

Bozkurt, A., & Göksel, N. (2018). Technology renovates itself: Key concepts on intelligent personal assistants (IPAs). In *Proceedings of 10th International Conference on Education and New Learning Technologies Conference, Palma, Spain* (pp. 2-4). https://doi.org/10.21125/edulearn.2018.1082

Clements, D. H., Sarama, J., Swaminathan, S., Weber, D., & Trawick-Smith, J. (2018). Teaching and learning Geometry: early foundations. *Quadrante*, *27*(2), 7-31. https://doi.org/10.48489/quadrante.22970

Crossley, N., Bellotti, E., Edwards, G., Everett, M. G., Koskinen, J., & Tranmer, M. (2015). *Social network analysis for ego-nets: Social network analysis for actor-centred networks*. Sage.

Cunha, G. C. A., Barraqui, L. P., & de Freitas, S. A. A. (2018). Evaluating the use of gamification in mathematics learning in primary school children. In *2018 IEEE Frontiers in Education Conference (FIE)* (pp. 1-4). IEEE. https://doi.org/10.1109/FIE.2018.8658950

Çulha, D. (2021). Competition-based learning of blockchain programming. *Journal of Educational Technology & Online Learning*, *4*(1), 46-55. https://doi.org/10.31681/jetol.831645

Denyer, D., & Tranfield, D. (2009). Producing a systematic review. In D. A. Buchanan & A. Bryman (Eds.), *The Sage handbook of organizational research methods* (p. 671–689). Sage Publications Ltd.

de Sousa Borges, S., Durelli, V. H., Reis, H. M., & Isotani, S. (2014). A systematic mapping on gamification applied to education. In *Proceedings of the 29th annual ACM symposium on applied computing* (pp. 216-222). https://doi.org/10.1145/2554850.2554956

Deterding, S. (2012). Gamification: designing for motivation. *Interactions*, *19*(4), 14-17. https://doi.org/10.1145/2212877.2212883

Deterding, S., Sicart, M., Nacke, L., O'Hara, K., & Dixon, D. (2011). Gamification. using game-design elements in non-gaming contexts. In *CHI'11 extended abstracts on human factors in computing systems* (pp. 2425-2428). https://doi.org/10.1145/1979742.1979575

Dicheva, D., Dichev, C., Agre, G., & Angelova, G. (2015). Gamification in education: A systematic mapping study. *Journal of Educational Technology & Society*, *18*(3). https://www.jstor.org/stable/10.2307/jeductechsoci.18.3.75

Dubinsky, E., & Wilson, R. T. (2013). High school students' understanding of the function concept. *The Journal of Mathematical Behavior*, *32*(1), 83-101. https://doi.org/10.1016/j.jmathb.2012.12.001

Eleyyan, S. (2021). The future of education according to the fourth industrial revolution. *Journal of Educational Technology & Online Learning*, *4*(1), 23-30. https://doi.org/10.31681/jetol.737193

Faiella, F., & Ricciardi, M. (2015). Gamification and learning: a review of issues and research. *Journal of e-Learning and Knowledge Society*, *11*(3). https://doi.org/10.20368/1971-8829/1072

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification. In *2014 47th Hawaii international conference on system sciences* (pp. 3025-3034). IEEE. https://doi.org/10.1109/HICSS.2014.377

Hanks, P. (2013). *Lexical analysis: Norms and exploitations*. Mit Press. https://doi.org/10.1075/ijcl.21.2.06teu

Huizinga, J. (1955). *Homo Ludens: A Study of the Play Element in Culture*. Boston: The Beacon Press.

Huotari, K., & Hamari, J. (2017). A definition for gamification: Anchoring gamification in the service marketing literature. *Electronic Markets*, *27*(1), 21–31. https://doi.org/10.1007/s12525-015-0212-z

Johnstone, B. (2018). *Discourse analysis*. John Wiley & Sons.

Jagušt, T., Botički, I., & So, H. J. (2018). Examining competitive, collaborative and adaptive gamification in young learners' math learning. *Computers & Education*, *125*, 444-457. http://doi.org/10.1016/j.compedu.2018.06.022

Kapp, K. M. (2012). *The gamification of learning and instruction: game-based methods and strategies for training and education.* John Wiley & Sons.

Kim, A. J. (2011). "Smart Gamification: Seven Core Concepts for Creating Compelling Experiences." Retrieved December 12, 2019, from http://www.youtube.com/watch?v=F4YP-hGZTuA.

Kaya, D., & Keşan, C. (2014). İlköğretim seviyesindeki öğrenciler için cebirsel düşünme ve cebirsel muhakeme becerisinin önemi [the importance of the algebraic thinking and algebraic reasoning skills for primary school students]. *International Journal of New Trends in Arts, Sports & Science Education (IJTASE)*, *3*(2). http://www.ijtase.net/ojs/index.php/IJTASE/article/view/299

Koçak, M., & Soylu, Y. (2018). Matematik öğretmeni adaylarının yüzey alan ve hacim konusunda öğretim strateji bilgilerinin incelenmesi [investigate of prospective mathematics teachers' teaching strategy knowledge in the context of the surface area and volume]. *International Journal of Educational Studies in Mathematics*, *5*(3), 78-97. https://dergipark.org.tr/tr/pub/ijesim/issue/40246/432201

Koivisto, J., & Hamari, J. (2014). Demographic differences in perceived benefits from gamification. *Computers in Human Behavior*, *35*, 179-188. https://doi.org/10.1016/j.chb.2014.03.007

Lakoff, G., & Núñez, R. (2000). *Where mathematics comes from* (Vol. 6). New York: Basic Books.

Lameras, P., & Moumoutzis, N. (2015). Towards the gamification of inquiry-based flipped teaching of mathematics a conceptual analysis and framework. In *2015 International Conference on Interactive Mobile Communication Technologies and Learning (IMCL)* (pp. 343-347). IEEE. https://doi.org/10.1109/IMCTL.2015.7359616

Landis, J.R., & Koch, G.G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*, 159- 174. https://doi.org/10.2307/2529310

Marin, A., &Wellman, B. (2011) Social network analysis: An introduction. In: Scott J and Carrington PJ (eds) *Sage Handbook of Social Network Analysis*. Thousand Oaks, CA: Sage, pp. 11–25. https://doi.org/10.1080/10572252.2014.942467

Marczewski, A. (2013). *Gamification: a simple introduction & A bit more-Tips, advice and thoughts on gamification*. [eBook edition]. Self-published.

Marczewski, A. (2019). Analogue vs digital gamification. Retrieved December 30, 2019, from https://www.gamified.uk/2019/04/26/analogue-vs-digital-gamification/

Martí-Parreño, J., Méndez-Ibáñez, E., & Alonso-Arroyo, A. (2016). The use of gamification in education: a bibliometric and text mining analysis. *Journal of computer assisted learning*, *32*(6), 663-676. https://doi.org/10.1111/jcal.12161

MoNE (2018). Matematik dersi öğretim programı ilkokul ve ortaokul 1-8. sınıflar [mathematics education programs for primary and middle school grades 1-8]. Turkish Head Council of Education and Morality, Ankara.

Muntean, C. I. (2011). Raising engagement in e-learning through gamification. In *Proc. 6th international conference on virtual learning ICVL* (Vol. 1, pp. 323-329). https://doi.org/10.12681/icodl.640

Nah, F. F. H., Zeng, Q., Telaprolu, V. R., Ayyappa, A. P., & Eschenbrenner, B. (2014). Gamification of education: a review of literature. In *International conference on hci in business* (pp. 401-409). Springer, Cham. https://doi.org/10.1007/978-3-319-07293-7_39

National Council of Teachers of Mathematics (NCTM). (2000). *Principles and Standards for School Mathematics*. Reston, Va.: NCTM.

Ortiz Rojas, M. E., Chiluiza, K., & Valcke, M. (2016). Gamification in higher education and stem: A systematic review of literature. In *8th International Conference on Education and New Learning Technologies (EDULEARN)* (pp. 6548-6558). Iated-int Assoc Technology Education A& Development. https://doi.org/10.21125/edulearn.2016.0422

Petticrew, M., & Roberts, H. (2008). *Systematic reviews in the social sciences: A practical guide*. John Wiley & Sons. https://doi.org/10.1080/14733140600986250

Riverra, J. & Van der Meulen, R. (2014). *Gartner's 2014 hype cycle for emerging technologies maps the journey to digital business*. Gartner, Stamford USA. Retrieved December 30, 2019, from https://www.gartner.com/en/documents/2809728/hype-cycle-for-emerging-technologies-2014

Rusinowska, A., Berghammer, R., De Swart, H., & Grabisch, M. (2011, May). Social networks: prestige, centrality, and influence. In *International Conference on Relational and Algebraic Methods in Computer Science* (pp. 22-39). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-21070-9_2

Tatar, E., & Dikici, R. (2008). Matematik eğitiminde öğrenme güçlükleri [learning difficulties in mathematics education]. *Mustafa Kemal Journal of University Social Sciences Institute*, *5*(9), 183-193. https://dergipark.org.tr/en/pub/mkusbed/issue/19561/208536

Toda, A. M., do Carmo, R. S., Mesquita, M. A., da Silva, A. L., & Brancher, J. D. (2014). A gamified online system to aid in math lessons of junior and middle high students. In *2014 IEEE International Conference on Computer and Information Technology* (pp. 616-621). IEEE. https://doi.org/10.1007/s12528-019-09221-2

Van Eck, N., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics, 84*(2), 523-538. https://doi.org/10.1007/s11192-009-0146-3

Van Klaveren, C., & De Wolf, I. (2015). Systematic reviews in education research: when do effect studies provide evidence. *Contemporary Economic Perspectives in Education*, 11-34. https://doi.org/10.2307/j.ctt14jxsqg.4

Watson, R. T., & Webster, J. (2020). Analysing the past to prepare for the future: Writing a literature review a roadmap for release 2.0. *Journal of Decision Systems*, *29*(3), 129-147. https://doi.org/10.1080/12460125.2020.1798591

Werbach, K., & Hunter, D. (2012). *For the win: How game thinking can revolutionize your business*. Wharton Digital Press, Philadelphia.

Widodo, S., & Rahayu, P. (2019). Analysis of elementary school students' mastery in math instruction based on arithmetic gamification. In *Journal of Physics: Conference Series* (Vol. 1157, No. 4, p. 042112). IOP Publishing. https://doi:10.1088/1742-6596/1157/4/042112

Zichermann, G., & Cunningham, C. (2011). *Gamification by design: Implementing game mechanics in web and mobile apps*. O'Reilly Media, Inc