Drawing the Big Picture of Games in Education: A Topic Modeling-Based Review of Past 55 Years

Abstract
The literature of games in education has a rich and multidisciplinary content. Due to the large number of studies in the field, it is not easy to analyze all relevant studies. There are few studies exploring the big picture of research trends in the field. For this reason, the purpose of this study is to examine longitudinal trends of game-based research in education using text mining techniques. 4,980 publications were retrieved as an experimental dataset indexed by the SCOPUS database in the period 1967 to mid-2021. The results include descriptive statistics of game-based research, trends of the research topics, and trends in the frequency of each topic over time. They show that the number of studies focusing on the use of games in education has increased, particularly since the 2000s when internet use accelerated and became widespread. Approximately 70% of all the studies were conducted in the last 10 years. One third of the studies is related to the main topic of game-based learning. It is significant that in the last three decades the topic of serious games has been among the top three trends. Considering usage acceleration of the topics, the highest values belong to game-based learning, serious games and student science games, in that order. The findings of this study are expected to guide the field by providing a better understanding of the trends of games in education and offer a direction for future research.

Keywords: Serious games, game-based learning, text mining, topic modeling, latent dirichlet allocation

1. INTRODUCTION

Humans have been playing games since ancient times; backgammon, for example, has been played for over 5,000 years (Dörner et al., 2016b). Games can be defined as a plastic environment that can be adapted to any technology from ancient times to the present (Costikyan, 2010). There are many types of games, from board games, puzzles, and card games, to console games, computer games, and role-playing games.

The literature provides no precise and single definition of games. Abt's definition of a game includes two adversaries trying to achieve an objective within a set of rules (1970). Examining eight different definitions of games in detail, Salen and Zimmerman (2004) stated that the most common points are that a game contains rules and is goal-oriented. They define a game as "a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome" (Salen & Zimmerman, 2004, p. 11). Games have been available in many fields for different purposes since ancient times.

Plaisent et al. (2019) emphasize that games can be classified differently. The purpose may be educational or informative. In addition, depending on the nature of the learning, games can be mental or physical (Plaisent et al., 2019). Throughout history, games have been used for learning purposes (Loh et al., 2015). The use of games in education is not a new topic (Plass et al., 2015). However, most games in education are based on technologies such as tablet, smartphones or high-speed computers (Hartt et al., 2020). With the increasing number of digital tools and digital media, researchers and educators' focus has been on games in education (Plass et al., 2020). Although there is no exact and precise definition, it is possible to define games in education as games that serve a specific learning purpose (Plass et al., 2020; Tsekleves et al., 2016). Games in education is far from "mere entertainment" (Shaffer et al., 2005); they have specific learning purposes. At this point, it would be appropriate to

mention about two concepts that are frequently mentioned in the literature: game based learning and serious games.

Education researchers and practitioners are increasingly focusing on serious games for education or game-based learning (GBL) which differ from commercial off the shelf and the drill-and-practice games in that they set the main goals as learning rather than entertainment (Hainey et al., 2016). Serious games and game based learning are often used interchangeably. Hainey et al. (2016) emphasized that GBL is sometimes used as a subcategory of serious games and sometimes as a synonym of serious games. *"Game-based learning (GBL) describes an environment where game content and game play enhance knowledge and skills acquisition, and where game activities involve problem solving spaces and challenges that provide players/learners with a sense of achievement "(*Qian & Clark, 2016, p.51). Kaimara et al. (2021) defines GBL as digital or non-digital learning environment that enables students to gain knowledge and skills.

Serious games, which are considered as umbrella terms, include different educational games (Backlund & Hendrix, 2013). The term serious game is used as an inclusive term under which to discussed these games in detail.

Serious games are a popular and promising alternative to traditional learning environments (Plaisent et al., 2019). Bakhuys Roozeboom et al. (2017) point out that serious games have yielded many positive outcomes and higher quality learning relative to the traditional learning environment. Games can help young people learn (Prensky, 2001). The term serious game was first used by Abt (1970), stating that serious games are for learning purposes. There is no single accepted definition of serious games. Dörner et al. (2016a) state that they are generally described serious games as games that have at least one purpose other than entertainment. A game is serious game if it aims to teach a concept in science, which is described as a characterizing goal (Dörner et al., 2016b). Although definitions of serious games include non-digital games, it usually refers to digital serious games (Backlund & Hendrix, 2013; Lamb et al., 2018). Non-digital games can be used for a serious purpose. For example, with its history dating back to 1400 BC, Mancala is a serious game that aims to teach accounting (Laamarti et al., 2014) and chess has been used for teaching military strategies (Loh et al., 2015). Board games have clearly been used as valuable educational tools (Plass et al., 2020). Serious games are used in fields from kindergarten to university, on-the-job training, vocational training, special education, and health education (Dörner et al., 2016a).

Slussareff et al. (2016) underline that games can be developed for cognitive, motor, affective, social areas, and even complex skills. They can improve results from mathematics teaching to problem solving in cognitive skills. Although there are mixed results, these games can help develop attitudes or improve motor skills. Multiplayer games can support social interaction. Moreover, they can also develop complex skills such as problem solving and hand-eye coordination (Slussareff et al., 2016).

The potential merits of serious games include enhancing learning (Hayes & Games, 2008; Ku et al., 2014), making lessons enjoyable, and increasing motivation and engagement (Ku et al., 2014; Girard et al., 2013; Torbeyns et al., 2015; Vankúš, 2021). However, benefits are not restricted to enhancing students' problem solving skills (Becker, 2007).

Serious games have yielded significant outcomes for different subject areas, for example mathematics (Barros et al., 2020; Beserra et al., 2014; Brezovszky et al., 2019), science (Baek et al. 2016), social studies (Cruz et al., 2017), language (Palomo-Duarte et al., 2016), and special education (Durkin et al. 2015).

Understanding the scope, trends, and future of games in education is essential for researchers and practitioners. However, it is not easy to analyze the numerous body of research that have emerged over many years and to illustrate the big picture. To that end, automated analyzes are important to present the popular topics of the large number of accumulated studies and the change of these topics over time (Blei & Lafferty, 2007). As researchers do not have the capacity to read and study the increasing games in education literature, one of the statistical methods that can help researchers is topic modeling

algorithms. Topic modeling algorithms analyze the terms in the articles, the themes contained, the links between the themes, and their changes over time (Blei, 2012). Topic modeling aims to reveal hidden semantic issues in a set of documents, allowing efficient analysis of large amounts of research (Blei, 2012; Blei & Lafferty, 2007). In current study, in order to be more comprehensive, the phrase "games in education" is used throughout this paper. The aim of this study is to reveal the topics and trends in game-based research in education between 1964-2021 using the topic modeling technique. Since studies in the literature generally focus on a limited time period or limited topics/sub topics in games in education, it is expected that this research will fill this gap. In the available literature, there is a scarcity of studies that review trends and changes in games in education. Such reviews are important as they provide a basis for the researchers to shed light on their future research, guide them and fill the gap in the literature.

In their review, Boyle et al. (2016) explored the contributions of serious play to learning, skill development and participation of young people over the age of 14, including 143 high-quality evidence studies published between 2009 and 2014. The learning outcomes of games for learning is common. STEM and health are the most widely used topics.

Clark et al. (2016) examined games and learning in their meta-analysis. In 209 comparisons, they concluded that games improve learning over non-game environments.

Ravyse et al. (2017), aiming to reveal game success factors, examined 63 studies between 2000 and 2015. Five main themes emerged: backstory and production, realism, artificial intelligence and adaptivity, interaction, and feedback and debriefing.

Lamb et al. (2018) conducted a meta-analysis on 46 empirical studies. Their aim was to compare the results associated with serious educational games, serious games, and educational simulations. They reveal that these games are different from each other but do not differ according to the traditional environment.

Calvo-Morata et al. (2020) examined the use of serious games as a means of identifying and preventing (cyber) bullying. The results of this systematic review show that there are many video games providing a range of strategies to deal with (cyber) bullying. However, most of the games that have important outputs such as raising awareness of specifically cyberbullying and creating empathy are not available.

Chang and Hwang (2019) carried out a systematic review of mobile game-based learning covering the years 2007-2016. Trends such as mobile game types, learning strategies, research methods, and participants were considered for mobile game-based learning.

Examining the studies shows they are either systematic reviews or meta-analyses made in a specific field, or studies conducted in a shorter time period. Looking at recent comprehensive studies, Lamb et al. (2018) conducted a meta-analysis investigating the effectiveness of serious games, educational games, and simulations, while Calvo-Morata et al. (2020) specifically focused on (cyber)bullying related games and Chang and Hwang (2019) focused on mobile games. However, this aims to draw a general picture for the subject of serious games for education over 55 years. Considering the reviews, it is clear that they cover limited topics such as the effect of games on learning over a limited period and lack exploration of the big picture of trends in games in education. In order to fill this gap in the literature, this study analysis all studies on games in education from 1967 to 2021 using the topic modeling technique. The key purpose of the study is to reveal the trends and changes game-based research in education and to guide researchers.

2. RESEARCH METHODOLOGY

The methodology of this study was designed to analyze four research questions:

RQ 1. What are descriptive characteristics of games in education research during the period 1967 and 2021?

RQ 2. What are the research topics in games in education during the period 1967 to 2021?

RQ 3. How have the topics of games in education changed over the past 55 years?

RQ 4. What are the future trends in games in education research?

To analyze the descriptive characteristics and research trends in games in education, the research methodology was designed considering the main steps of descriptive and topic modeling analysis. The research mainly consists of 3 sub-processes: (1) data retrieval (2) descriptive analysis, and (3) topic modeling (See Figure 1). Detail of these sub-processes are given in the following sections.

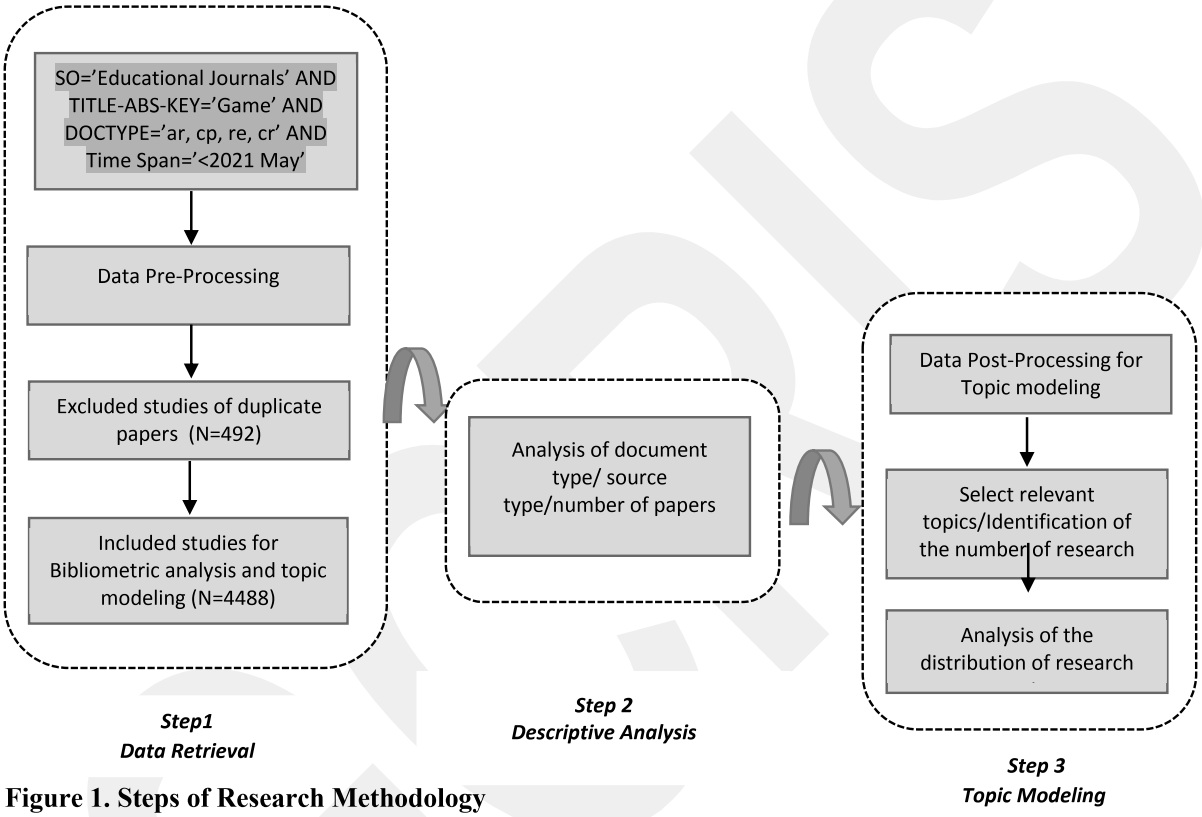


Figure 1. Steps of Research Methodology

2.1 Data Retrieval

The Web of Science, Elsevier Scopus, and Google Scholar are the most important electronic sources in bibliometric and text mining analysis. Due to Google Scholar not having a database feature as does Web of Science and Scopus, it is not possible to download articles in bulk from this system. For this reason, Web of Science and Elsevier Scopus were utilized as a data source and searched with the same search query. When the search results of the two databases are compared, the number of articles belonging to the relevant search query is higher (Scopus=4,980/ Web of Science=4,389) in Elsevier Scopus due to the fact that the Scopus database covers more journals (Mongeon & Paul-Hus, 2016). For this reason, Elsevier Scopus was preferred as a data source.

In topic modeling and descriptive analysis, title, abstract, and keywords are the primary material of the bibliometric and text mining analysis. For this reason, we search the term "game" in these sections of the publications, which was the topic word of the research. Details of the search term is given in Figure 1(first box in Step 1). The search was restricted to education and limited to journal articles and proceedings papers, excluding other resources such as reviews and editorial material (See Figure 1). In

total, 4,980 journal publications written in English before May 2021 were retrieved as an experimental dataset. In the data preprocess 1 step, a total of 492 publications that do not have an abstract (352) or have the same abstract (140) were extracted from the data. Examination of the abstract section of 4,980 papers showed that 392 articles did not have an abstract section. All these 392 articles were published between 1935 and 2003. The articles were scanned into the system and uploaded in image file format, therefore, data belonging to some fields such as the abstract could not be automatically retrieved by the Scopus database. In addition, duplicate copies of 140 articles with the same abstract information were removed from the dataset. Then, the affiliation section in the dataset was converted into a format suitable for bibliometric analysis. As a result, 4,488 publications were included for bibliometric analysis and topic modeling.

2.2 Descriptive Analysis

Descriptive analysis provides a numerical display of publications produced by individuals or institutions in a certain time period and certain region and the relations between these publications (Donthu et al., 2021; Small, 1999; Thelwall, 2008). In descriptive analysis, research articles are examined within the framework of different bibliometric characteristics such as subject, year, contributors, keywords, and findings related to scientific communication (Donthu et al., 2021; Huang et al., 2020;). The most influential authors and publications can be found with this analysis (Franceschini et al., 2015; Heradio et al., 2016). In the descriptive analysis step of this study, the aim is to examine the researches on game by revealing the status of the number of papers according to the publication source, publication type, and years published.

2.3 Topic Modeling

Topic modeling is an unsupervised machine learning technique which automatically analyzes text data to discover the abstract "topics" in a large volumes of text. A "topic" is defined as a collection of related words appearing together (Blei et al., 2003). The Latent Dirichlet Algorithm (LDA) is the most used algorithm in topic modeling (Jelodar et al., 2019). LDA considers each document as a collection of topics and each topic as a collection of keywords in a certain proportion (Blei et al., 2003). It calculates the topics per document and words per topic based on the distribution of words in the documents. It uses iterations of the Dirichlet distribution. More specifically, LDA text mining algorithm is used to automatically reveal the hidden semantic topic structures from document collections (publications in this research).

2.3.1 LDA Implementation and Model Tuning

In this study, LDA was applied using the LdaModel library provided by the Gensim package in Python programming language. The most important tuning parameters for LDA models are Alpha (α), Beta (β), and number of topics (K) (Blei et al., 2003). The parameter α represents per-document topic density and β represents per-topic word density. With a higher alpha, documents are made up of more topics, and with a higher beta, topics are made up of most of the words in the corpus (Blei et al., 2003). Depending on these tuning parameters, perplexity and coherence scores are generated, which show the how good the chosen topic model is (Blei et al., 2003; Hasan et al., 2021). Topic coherence and perplexity scores are the main techniques used to estimate the number of topics. The α and β parameters were tested with a value recommended in the literature for short texts (50/K) (Lu et al., 2011; Steyvers & Griffiths, 2007). Another critical parameter of the LDA model, K, which reflects the number of subjects, was also used in the model fitting. When the K parameter is increased, finer-grained topics are created, but when it is decreased, coarser-grained topics are created (Lu et al., 2011; Jelodar et al., 2019). To decide on the suitable or optimal number of topics (K), the LDA model was built and explored with varied K-values (5, 6, 7, and 60) for defined α and β values. According to the results of a number of iterations, the desired values for coherence and perplexity scores were achieved when the number of topics was equal to 18.

3. RESULTS

3.1 Descriptive Analysis Result (RQ 1)

To better understand the descriptive characteristic of the collected data (RQ 1), the distribution of the articles by year, publisher, and publication types were analyzed. Table 1 shows the number of publications according to ten-year periods. Initial studies indexed by the SCOPUS database were published in 1968. After this year, the field evolved and there were an increasing number of studies. It is seen that the number of articles between 1972-2001 covers approximately 5% of the total articles, and there is a sharp increase especially after 2002. While the years 2002-2011 represented 24.6% of the total publications, the total number of publications between 2012-2021 increased approximately 3 times and covered 70.4%.

Table 1. *Distribution of Publications in Ten-year periods*

Yearly Periods	**n**	**%**
1968-1971	3	0.1%
1972-1981	50	1.1%
1982-1991	58	1.3%
1992-2001	113	2.5%
2002-2011	1,103	24.6%
2012-2021	3,159	70.4%
Total	4,488	100.0%

Table 2 shows the top 10 publication sources of the analyzed studies. The publications with the highest percentage, 27.8%, are "Computers and Education" journals (n=317), followed by “Proceedings - Frontiers in Education Conference, FIE” with 216 studies (18.9%) and “Journal of Physical Education and Sport”. In addition, it is noteworthy that two of the top 10 publication sources are related to physical education and sport.

Table 2. *Publication Sources*

Source Name	**No. of Papers**	**%**
Computers and Education	317	27.8%
Proceedings - Frontiers in Education Conference, FIE	216	18.9%
Journal of Physical Education and Sport	125	11.0%
IEEE Global Engineering Education Conference, EDUCON	118	10.3%
Journal of Chemical Education	92	8.1%
Annual Conference on Innovation and Technology in Computer Science Education, ITiCSE	64	5.6%
Education and Information Technologies	62	5.4%
International Journal of Engineering Education	57	5.0%
European Physical Education Review	45	3.9%
Journal of Economic Education	45	3.9%
Total	1,141	100.0%

Table 3. *Publication Type*

Type	No.	%
Journal Article	2,549	56.8%
Conference Paper	1,829	40.8%
Review	105	2.3%
Conference Review	5	0.1%
Total	4,488	100.0%

Table 3 shows the types of publications that were analyzed. 56.8% of the total publications were articles (n=2549), 40.8% were conference papers (n=1829), and 2.3% were conference reviews (n=105).

3.2 Topic Modeling Results (RQ 2)

In order to discover the research topics in games in education (RQ2), a topic modeling analysis was conducted. The LDA-based topic-modeling analysis found 18 topics from the collected data containing 4,488 articles. Table 4 shows these topic labels with the keywords of each topic. The topic labels were given by considering the top-ranked keywords in each topic. In most cases, the first five keywords were combined in a meaningful manner to name each topic. As seen in Table 4, the top-rated topics were "Game-based learning" (34.6%), "Serious game" (16.6%), "Student Science Game" (10.4%), "Student assessment" (9.5%), "Games" (6.0%), and "Simulation Games" (5.0%).

Table 4. *LDA Topics*

# of Topic	Topic Keywords	Topic Label	No. of Papers	%
T 2	learn, learning, learner, game-based, study, motivation, game, digital, environment, student, style, instructional, enhance, engagement, support	game-based learning	1,553	34.6%
T 14	serious, game, learn, education, educational, environment, develop, paper, tool, teach, development, skill, virtual, method, technology	Serious game / virtual games in engineering education	743	16.6%
T 10	student, science, game, class, card, lecture, classroom, concept, format, teach, play, activity, course, understand, school	student science game/ studies include card games in science teaching	465	10.4%
T 7	student, test, control, assessment, score, study, attitude, compare, measure, method, game, intervention, assess, medical, experimental	student assessment	425	9.5%
T 15	teacher, game, school, study, education, classroom, pupil, social, educational, practice, article, culture, people, female, examine	games	271	6.0%
T 19	simulation, game, management, decision, business, process, paper, experience, development, issue, education, practice, curriculum, develop, time	simulation games	225	5.0%
T 13	play, video, online, game, social, efficacy, adult, parent, leadership, multiplayer, player, power, relationship, woman, gaming	social game play/play online video social games	181	4.0%
T 4	design, game, project, base, development, user, framework, evaluation, paper, develop, approach, experience, create, educational, process	game design/game project design	169	3.8%

T 18	performance, game, sport, player, task, coach, competition, study, level, skill, time, difference, team, play, training	performance game in sport	149	3.3%
T 6	physical_education, teaching, lesson, nursing, staff, approach, unit, government, programme, nurse, music, invasion, discourse, centre, care	physical education	86	1.9%
T 17	child, mathematic, mathematical, skill, game, solve, ability, play, activity, study, math, architecture, cognitive, age, development	child mathematic / child mathematical skill	83	1.8%
T 9	game, simple, mobile, laboratory, rule, visual, medium, engine, history, graphic, application, adventure, element, object, chemistry	simple mobile games/mobile laboratory games	52	1.2%
T 5	programming, program, language, girl, boy, write, creative, compute, curriculum, faculty, creativity, career, computing, science, workshop	programming languages	31	0.7%
T 11	health, adolescent, planning, model, internet, day, hold, device, phase, risk, robot, human, target, commercial, people	adolescent health planning	25	0.6%
T 3	gamification, training, train, movement, motor, train, psychological, ecological, primary_school, personality, brain, empathy, publication,workplace, trainer	training gamification	11	0.2%
T 12	team, behavior, individual, action, cooperation, monitor, distribution, disability, distance, typical, record, package, organization, operation, success	team behaviour/team cooperation	11	0.2%
T 16	strategy, assignment, player, competitive, decision, event, behaviour, win, efficiency, strategic, choice, situation, type, serve, tactic	strategy assignment/ competitive games/ strategy games	5	0.1%
T 8	community, story, economic, literacy, read, environmental, text, flexible, dilemma, ethic, reading, status, incentive, voice, entry, community	community	3	0.1%

3.3 Results of Volume Analysis of Each Topic (RQ 3)

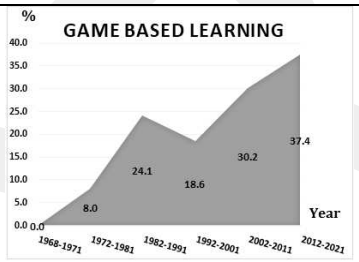
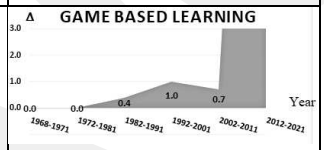
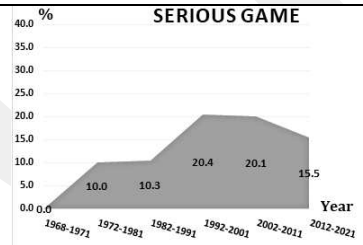
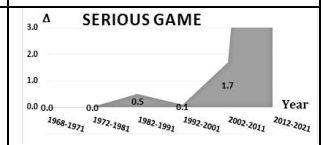
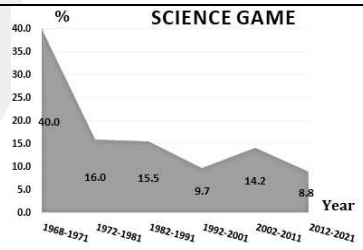
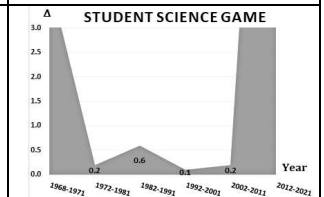
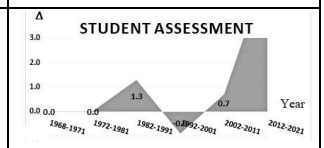
To discover how the trends and evolutions in each topic change over time (RQ3), details of the discovered topics for each decade were calculated. In this context, volume analysis of each topic was calculated. Table 5 shows the top three trend topics in decades. Trend topics were determined by considering the total number of articles published in 10-year periods. "Student assessment" was the highest trending topic in researches related to games between 1972-1981, while "game based learning" stands out between 1982-1991. Between 1992-2001, the publications on "serious game" increased in total and became a trend topic. In the following 10-year periods, the studies on "game-based learning" and “serious games” are more prominent.

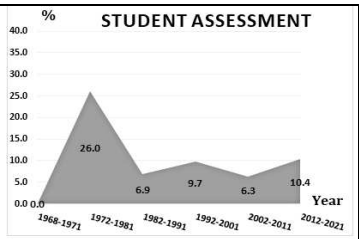
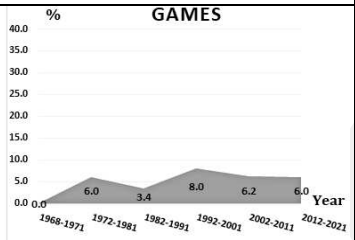
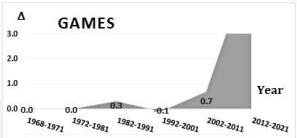
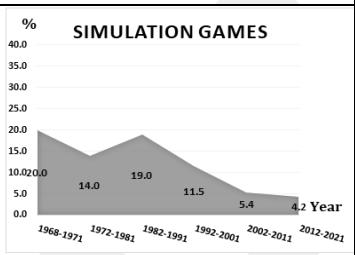
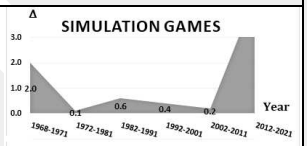
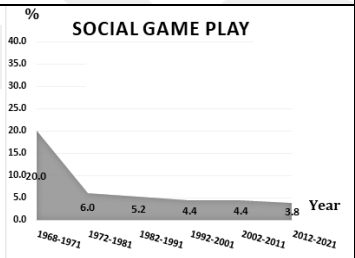
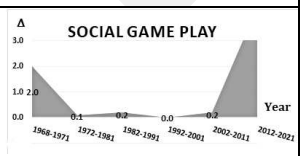
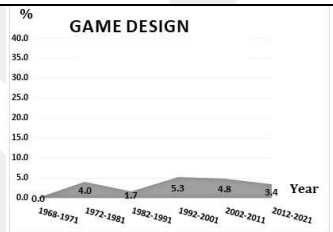
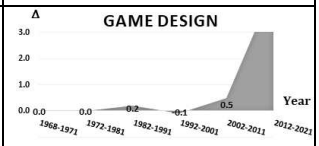
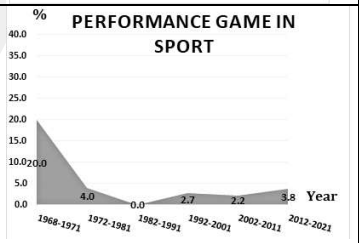
Table 5. *Top Three Trend Topics in Decades*

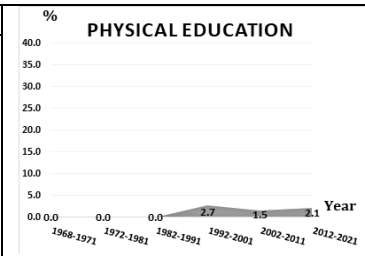
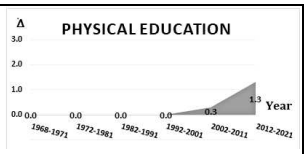
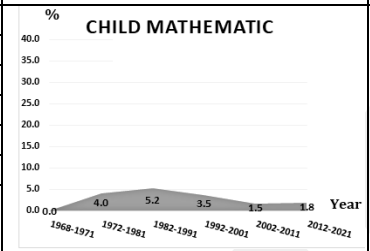
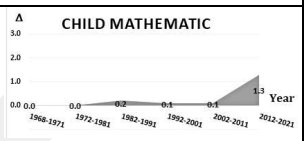
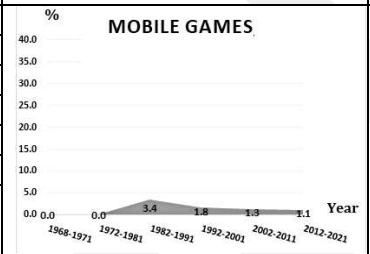
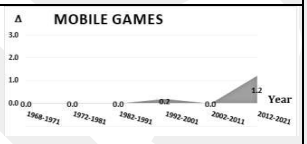
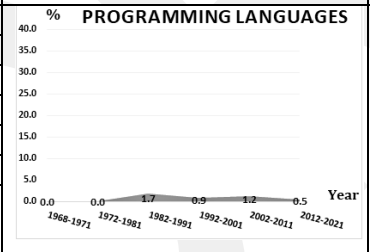
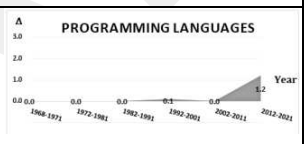
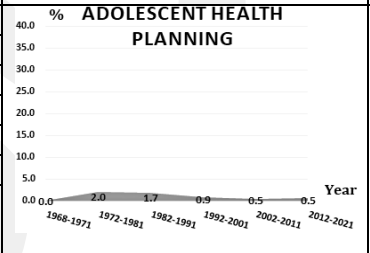
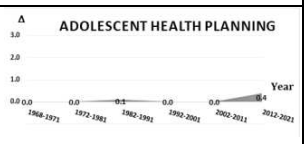
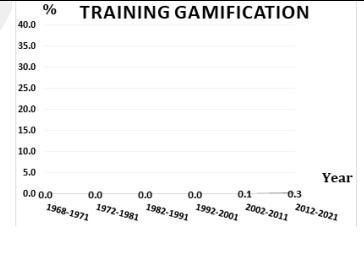
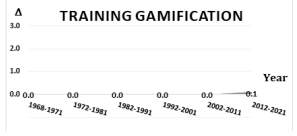
1972-1981	student assessment	card games	game-based learning
1982-1991	game based learning	simulation games	card games
1992-2001	serious game	game-based learning	simulation games
2002-2011	game-based learning	serious game	card games
2012-2021	game-based learning	serious game	student assessment

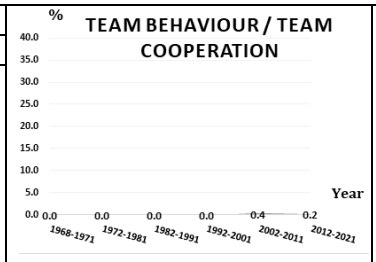
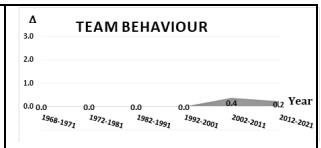
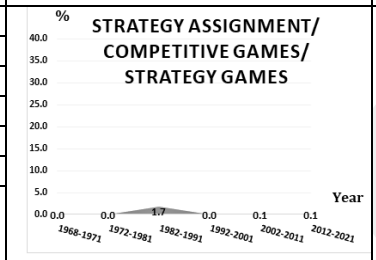
Table 6 shows the number of articles, percentage distribution, and acceleration value by topics for 5 decades from 1972 to 2021. The acceleration value is calculated by taking the difference in the number of articles between the current decade and the previous decade and by dividing by 10. Table 6 shows that the mean rate and acceleration value in the decade differs for each topic. In addition, the number of articles for each topic varies depending on the years. Figure 2 shows the average topic percentages, which is calculated considering topic percentages over each decade for each topic. The topic percentage in each decade was calculated considering the number of publications in the relevant decade. Topic percentages in each decade and average topic percentages can be seen in the rows indicated by % in Table 6. Accordingly, "game-based learning" corresponds to (19.7%) of the related studies in all decades, respectively, "student science game" (17.4%), serious game (12.7%), "student assessment" (9.9%) and "games" (4.9%).

Table 6. *Mean and Acceleration Values (∆) of Topic According to Decade*

Topic Label		N	%	∆	Mean Volume Graph	Acceleration Graph
game-based learning	1968-71	0	0.0	0.0		
	1972-81	4	8.0	0.0		
	1982-91	14	24.1	0.4		
	1992-01	21	18.6	1.0		
	2002-11	333	30.2	0.7		
	2012-21	1181	37.4	31.2		
	AVG	258.8	19.7	5.6		
serious game	1968-71	0	0	0		
	1972-81	5	10	0		
	1982-91	6	10.3	0.5		
	1992-01	23	20.4	0.1		
	2002-11	221	20.1	1.7		
	2012-21	488	15.5	19.8		
	AVG	123.8	12.7	3.7		
student science game	1968-71	2	40	4		
	1972-81	8	16	0.2		
	1982-91	9	15.5	0.6		
	1992-01	11	9.7	0.1		
	2002-11	156	14.2	0.2		
	2012-21	279	8.8	14.5		
	AVG	77.5	17.4	3.3		
student assessment	1968-71	0	0	0		
	1972-81	13	26	0		
	1982-91	4	6.9	1.3		
	1992-01	11	9.7	-0.9		
	2002-11	69	6.3	0.7		
	2012-21	328	10.4	5.8		

	AVG	70.8	9.9	1.2		
games	1968-71	0	0	0		
	1972-81	3	6	0		
	1982-91	2	3.4	0.3		
	1992-01	9	8	-0.1		
	2002-11	68	6.2	0.7		
	2012-21	189	6	5.9		
	AVG	45.2	4.9	1.1		
simulation games	1968-71	1	20	2		
	1972-81	7	14	0.1		
	1982-91	11	19	0.6		
	1992-01	13	11.5	0.4		
	2002-11	59	5.4	0.2		
	2012-21	134	4.2	4.6		
	AVG	37.5	12.4	1.3		
social game play	1968-71	1	20	2		
	1972-81	3	6	0.1		
	1982-91	3	5.2	0.2		
	1992-01	5	4.4	0		
	2002-11	48	4.4	0.2		
	2012-21	121	3.8	4.3		
	AVG	30.2	7.3	1.1		
game design	1968-71	0	0	0		
	1972-81	2	4	0		
	1982-91	1	1.7	0.2		
	1992-01	6	5.3	-0.1		
	2002-11	53	4.8	0.5		
	2012-21	107	3.4	4.7		
	AVG	28.2	3.2	0.9		
Performance game in sport	1968-71	1	20	2		
	1972-81	2	4	0.1		
	1982-91	0	0	0.1		
	1992-01	3	2.7	-0.2		
	2002-11	24	2.2	0.3		
	2012-21	119	3.8	2.1		
	AVG	24.8	5.5	0.7		
physical education	1968-71	0	0	0		
	1972-81	0	0	0		
	1982-91	0	0	0		
	1992-01	3	2.7	0		
	2002-11	16	1.5	0.3		

	2012-21	67	2.1	1.3		
	AVG	14.3	1.1	0.3		
child mathematic	1968-71	0	0	0		
	1972-81	2	4	0		
	1982-91	3	5.2	0.2		
	1992-01	4	3.5	0.1		
	2002-11	17	1.5	0.1		
	2012-21	57	1.8	1.3		
	AVG	13.8	2.7	0.3		
mobile games	1968-71	0	0	0		
	1972-81	0	0	0		
	1982-91	2	3.4	0		
	1992-01	2	1.8	0.2		
	2002-11	14	1.3	0		
	2012-21	34	1.1	1.2		
	AVG	8.7	1.3	0.2		
programming languages	1968-71	0	0	0		
	1972-81	0	0	0		
	1982-91	1	1.7	0		
	1992-01	1	0.9	0.1		
	2002-11	13	1.2	0		
	2012-21	16	0.5	1.2		
	AVG	5.2	0.7	0.2		
adolescent health planning	1968-71	0	0	0		
	1972-81	1	2	0		
	1982-91	1	1.7	0.1		
	1992-01	1	0.9	0		
	2002-11	5	0.5	0		
	2012-21	17	0.5	0.4		
	AVG	4.2	0.9	0.1		
training gamification	1968-71	0	0	0		
	1972-81	0	0	0		
	1982-91	0	0	0		
	1992-01	0	0	0		
	2002-11	1	0.1	0		
	2012-21	10	0.3	0.1		
	AVG	1.8	0.1	0		
team behaviour/team	1968-71	0	0	0		
	1972-81	0	0	0		
	1982-91	0	0	0		
	1992-01	0	0	0		

cooperation	2002-11	4	0.4	0		
	2012-21	7	0.2	0.4		
	AVG	1.8	0.1	0.1		
strategy games	1968-71	0	0	0		
	1972-81	0	0	0		
	1982-91	1	1.7	0		
	1992-01	0	0	0.1		
	2002-11	1	0.1	-0.1		
	2012-21	3	0.1	0.1		
	AVG	0.8	0.3	0		

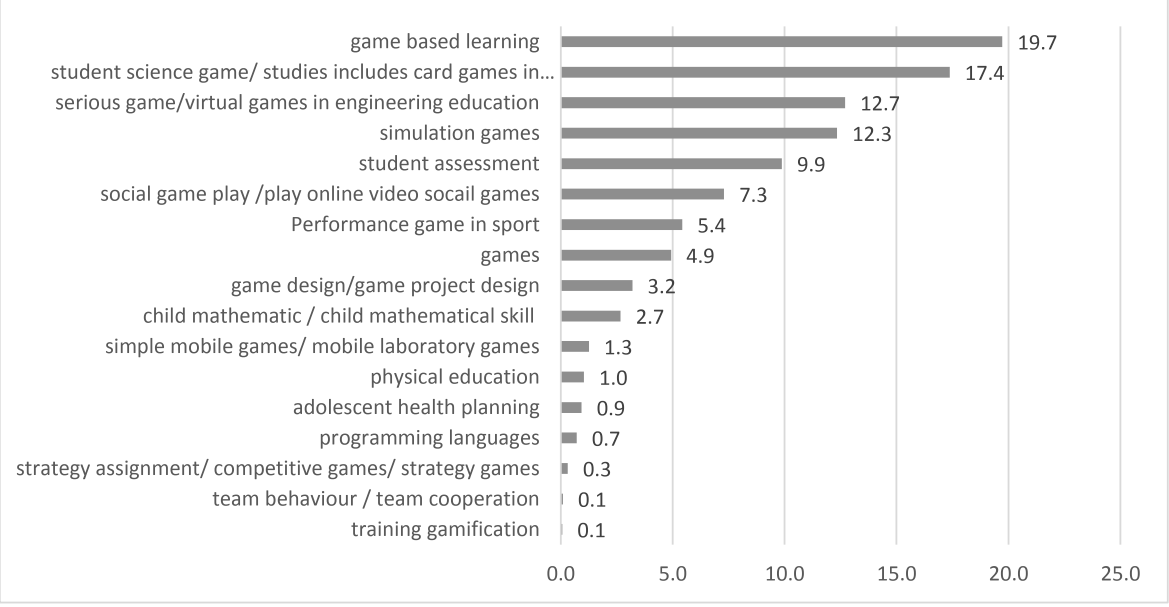


Figure 2. A*verage topic percentages considering number of papers/publications by decade*

Table 7 shows the first 10 of the most widely published subject areas. The subject areas cover a broad range. Computer science and education fields are in the first two places, while management of technology and innovation, and developmental and educational psychology take the last two places.

Table 7. Subject Areas

Areas	**N**	**%**
Computer Science	745	16.60
Education	490	10.92
Software	233	5.19
Computer Science Applications	170	3.79
Engineering (all)	156	3.48
Chemistry	133	2.96
Physical Therapy, Sports Therapy and Rehabilitation	126	2.81
Information Systems and Management	90	2.01
Management of Technology and Innovation	70	1.56
Developmental and Educational Psychology	68	1.52
TOTAL	2,281	50.84

3.4 Result of Acceleration Analysis (RQ 4)

In order to better understand the future trends in games in education research (RQ 4), acceleration values (Δ), shown in Table 6, were analyzed for each topic in each decade. It was calculated considering the change in the number of papers between the current and previous decades. Average acceleration values for each topic is given in Figure 3. Accordingly, the speed considering the changes in the number of publications for the topics “Game- based Learning”, “Serious game”, and “Student Science Game” can be considered as very fast (higher than 3.0). The speed of the topics, namely, “Simulation Games”, “Student Assessment”, and “Social Game Play” can be considered as fast (between 0.6 and 1.4). The other topics can be considered as slow (lower than 0.4).

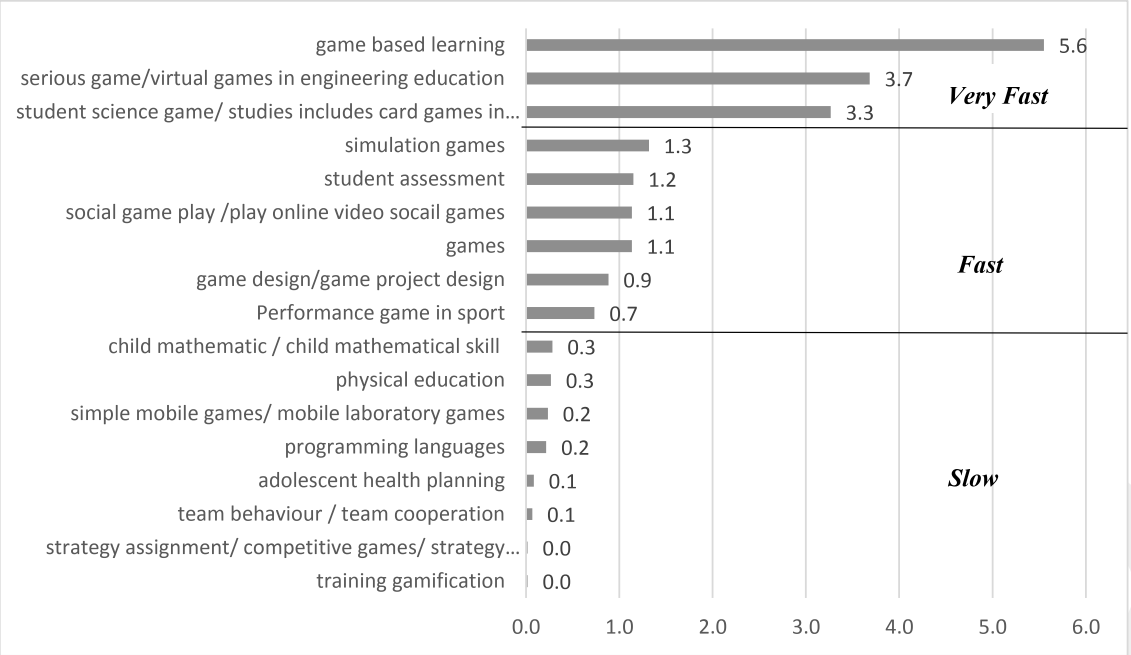


Figure 3: Acceleration Speed of Topics

4. DISCUSSION

4.1 Increase in the number of game researches in the last two decades (RQ1)

As can be seen from the distribution of publications on the use of games in education by years (Table 1), a slow increase is seen until 2002 and a 10-fold increase in the 2002-2011 decade. Similarly, Wouters and Van Oostendorp (2013) observe this increasing interest for serious game or game-based learning. In particular, the widespread use of the Internet may have caused this increase. Games played over the internet and the fact that the games are more accessible may also have affected the situation. Moreover, there is a 3-fold increase in the 2012-2021 decade. In fact, the last decade accounts for 70% of all publications. Although the term serious game has been around for 50 years, it has been used for the last two decades and it seems that the studies are intensifying daily. Similarly, Lamb et al. (2018) highlight that owing to developments in computing, serious games have reached a wide area of use in education, which is a relatively recent subject. From this point of view, it can be said that the use of games in education has increased in parallel with technological developments. With the use of personal computers, internet, advanced graphics technologies and artificial intelligence algorithms, the tendency to use games in education has also increased. At this point, especially in this time period (2012-2021), the increase in the number of mobile devices, the pervasive use of mobile games, and the fact that games are more accessible may have affected the increase. According to Palomo-Duarte et al. (2016) there is a wide range of mobile games available for many different areas. Using mobile devices in games in education can be an advantage for accessibility. In line with this, Yallihep and Kutlu (2020) stated that mobile educational games have an advantage because they can include mobile devices and game experience to attract the attention of children in the digital age. Tsekleves et al. (2016) and Connolly et al. (2012) also report that the popularity of games increased with high technology such as high-end game consoles, internet and mobile devices. In parallel with this, Lamb et al. (2018) emphasize that with the development of computer hardware (processor, memory, graphics cards, etc.), the playability of serious educational games became stronger in the 2000s with the development of more realistic 3D games and the use of these games on personal computers.

4.2 Insufficient number of robust researches (RQ1)

As can be seen from Tables 2 and 3, almost half of the publications are articles. Conference papers are the remaining half. In other words, a number of studies are from conference presentations rather than peer-reviewed journals. According to Vardi (2009) conference papers often do not go through a careful review process. In addition, very few of the conference papers are converted into articles. The journal article is a powerful product for reporting scientific research in many academic fields (Vrettas & Sanderson, 2015). These studies may be of high quality, but conference papers provide more limited information by nature. The credibility for conference papers may less robust compared to journal articles. Conference paper can be seen as less mature and less elaborate (González-Albo & Bordons, 2011). This situation shows that more robust should be done on the use of games in education. There is a huge gap in the literature on this subject. The fact that games are used from a very young age and become a part of our lives indicates the importance of using game techniques in education. Robust experimental research (Smith et al., 2015) on the subject should be conducted. In line with this, Connolly et al. (2012) suggest that, in particular, more robust studies are needed to understand the effectiveness of games.

4.3 Massively increasing number of games and the importance of well-designed games (RQ2)

As can be seen in Table 4, the subject of game-based learning is found in approximately one-third of the publications. While a low acceleration was observed between 1968 and 2011, it can be said that the acceleration increased noticeably in the last decade. Serious games increased with a slow acceleration until the last decade, and the acceleration increased immensely in the last decade. It should be investigated why the number of publications on the use of these topics in education has decreased recently.

In the last 10 years, great developments have been experienced in game technologies. In addition, the increase in the production of these technologies has made them accessible. As the researchers accessed these game technologies, they started to be applied in their studies and examined their effects. However, it is important that the games are well designed, not the number. Instructionally, well designed games are only possible with interdisciplinary teamwork, as aspect the literature points to (Altizer Jr et al., 2017; Ke et al, 2019).

Game design requires skills such as interface designer, tester, programmer, sound engineer from different disciplines (Hsu & Wang, 2010). Dörner et al. (2016a) emphasize that games have interdisciplinary lens from different disciplines such as psychology and pedagogy, or sociology and economics. Developing serious games is a process involving many disciplines. One of these is instructional design (Blumberg et al., 2013; De Freitas, 2018). There is a need for games with well-designed instructional design. Since educational sciences have been developed with the perspective of different fields such as neuroscience, informatics science, and computer science, the term serious games have begun to leave its place to the term game science (De Freitas, 2018). Developing serious games of high quality is only possible with interdisciplinary cooperation (Dörner et al., 2016b).

4.4 Increase in the number of games developed in science and physical education (RQ3)

Science education is another important trending topic. By its nature, the field of science is more difficult. For this reason, studies are more concentrated in this area. The use of games and simulations in science education dates back to the 1970s and early 1980s (Ellington, 1981). Serious games are effective in teaching complex subjects (Plaisent et al., 2019). There are also meta-analyses and studies supporting this (Boyle et al., 2016; Hainey et al., 2016). Hainey et al. (2016) show that serious games are mostly developed in the field of science after mathematics. Slussareff et al. (2016) underline that the best results were obtained in science fields such as biology and physics. On the other hand, the interest in STEM education in recent years and the fact that it has attracted a lot of attention in this field (Le Thi Thu et al., 2021) may be among the reasons for this situation.

On the other hand, as seen in Table 2, two of the top 10 publication sources are related to physical education and sport. There is an increase in the number of games developed in physical education (see Mean Volume graph for topic “Physical Education” in Table 6). Electronic games in particular have been widely used in physical education and sports (Lonsdale at al., 2013; Papastergiou, 2009). Electronic games hold promise for physical education (PE). The most reported research studies into electronic games in PE were (a) enjoyment and motivation for physical exercise (Sell et al., 2008), (b) physical activity and fitness levels (Unnithan et al., 2006), (c) knowledge acquisition understanding of PE concepts (Bartholomew et al., 2000; Hornung et al., 2000), (d) acquisition of motor skills (Ciavarro et al., 2005; Fery & Ponserre, 2001), and (e) teamwork and social skills, in comparison to traditional PE activities (Hayes & Silberman, 2007). Moreover, Gesture-based systems allow users to interact with a wide variety of devices such as mobile phones, tablets, game consoles or computer systems (Chen & Fang, 2014). The widespread use of gesture-based systems such as Kinect and Wii in the field of game may also have contributed to the increase in the field of physical education.

4.5 The Interdisciplinary nature of games (RQ3)

Table 7 shows the first 10 of the most widely published subject areas. Considering that the publications are about games and education, it is very normal to have computer science and education fields in the first two places. However, the inclusion of different fields in this table is worth discussing. The fact that the fields of engineering, chemistry, physical therapy, sports therapy and rehabilitation, management of technology and innovation, developmental and educational psychology are also in this table shows that the use of games in education is a method used in many fields. Research conducted by Çiftci (2018) supports this result. He found in the bibliometric analysis of 1,412 publications that the "serious game" is also a popular topic for studies in different disciplines. The reason why only 10 fields are shown in the table is that there are too many field publications (n=31). The publications related to the fields in the table constitute half of all publications. In addition, there are also publications in fields such as nursing, medicine, applied mathematics, public health, sociology and political science, library and information sciences. In particular, the multitude of fields related to health attracts attention.

4.6 The necessity of developing games in different fields (RQ4)

Looking at the topics in Table 6, games have been used in many different educational fields, including different subjects such as assessment, physical education, coding, health, teamwork, and sports (Connolly et al., 2012; Hainey et al., 2016). This situation also emphasizes the necessity of using games in these fields. If a serious investment is made in these field, using games in education will both increase the motivation and engagement of students (Girard et al., 2013; Ku et al., 2014; Torbeyns et al., 2015; Vankúš, 2021) and enhance learning (Hayes & Games, 2008; Ku et al., 2014).

4.7 Transition to Serious Educational Games and Game-based Learning Terms (RQ4)

Game-based learning (GBL), which is used interchangeably or synonymously with serious game (SG) in the literature, is our first trend topic. Tsekleves et al. (2016) state that both GBL and SG are associated in the literature because they have a learning purpose. The authors also point out that GBL differs from serious games mainly based on video games as it includes not only video games but also different game platforms such as card games. Numerous qualitative and quantitative studies have been conducted on serious games, and review studies point to the potential of serious games (Boyle et al., 2016; Clark et al., 2016; Girard et al., 2013; Wouters et al., 2013; Wouters & Van Oostendorp, 2013).

An important emerging trend topic is "serious educational game". In support of this, Lamb et al. (2018) also state that with the maturation of games in the literature, the term serious educational game (SEG) began to be used more specifically. In addition, Annetta (2010) states that serious educational games

are games for the K-20 curriculum as they connect the real world with school curriculum content. Another difference between SG and SEG is that SG requires a more powerful computer platform, which can be difficult for schools to access (Lamb et al., 2018). Serious game applications are ever-increasing. Serious games, which are a powerful tool for gaining technical knowledge, strategic thinking, and strengthening collaborative work, make contributions in many areas (Plaisent et al., 2019). Due to the ever-increasing field of application, the terms serious educational game and game-based learning may have started to be used. In addition there is an increase in the use of games in the field of education due to their potential mentioned in, thus there is a field-specific transition in the number of research as mentioned before.

CONCLUSION

The aim of this study is to examine the game-based research in educational studies in general by reviewing the researches carried out between 1967-2021 (mid). For this purpose, topic modelling-based content analysis was conducted on the publications in the SCOPUS database to discover the themes and temporal trends of the studies. Previous trend studies on games in education have primarily relied on quantitative and qualitative examination of chosen publications and articles. However, the methodology used in this study sets it apart from past research. This method allows for the analysis of a relatively long period of time (55 years) and thousands of publications. As a result, the publications containing the use of games in education focused on 18 topics. With the themes discovered, researchers can see different dimensions of games in education and the changes in terms. This study illustrates how the rate of focus on these issues has changed over 55 years, which topics trended in how much time, and which topics are discussed together with other topics. Although this study covers 55 years, it is possible to observe various changes in these dimensions discovered in the field of games in education over the years. It is recommended for further research to conduct such studies periodically, to observe the developments over time, and to guide the studies related to games in education.

The study shows that the number of studies focusing on the use of games in education has increased, particularly since the 2000s when internet use accelerated and became widespread. Approximately 70% of all the studies were conducted in the last 10 years. Most of the studies are articles published in *Computers and Education Journal* and papers presented at the Frontiers in Education Conference. About half of the studies are journal articles. In addition to the increase in the number of games, there is a need for well-designed and interdisciplinary games and research on these games. For future studies, it is recommended to increase the quality of games by developing well-designed games with an interdisciplinary study.

One third of the studies relate to the main topic of game-based learning. It is significant that over the last three decades the topic of serious games has been among the top three trends. Developments in computer technologies and, in particular, the internet can be considered the main reasons for this. Considering the usage acceleration of the topics, the highest values belong to game-based learning, serious games and student science games, in that order. It is expected that game development and research will be carried out in future studies in different fields apart from the fields of science and physical education. In addition, due to the interdisciplinary nature of game development, it is recommended that researchers and practitioners from different fields can develop games in collaborative way and conduct research on games in education. In this way, it may be possible to enrich the games in education field.

These themes can be considered to support research on games in education and to use these themes in future research. The study sheds light on games in the education field in a way that offering insights into future direction of the field. Thus the study is expected to guide researchers and practitioners. In the light of all this information, our study has confirmed that the use of games in education can be applied in many fields of study and highlights its necessity. These findings not only point to the

interdisciplinary nature of games in education, it also shows the breadth of the diverse area that contributes.

In this study, analyzes were carried out using text mining techniques. However, such studies in the literature can be verified or elaborated by future studies, as much as possible, by field experts. Also, the technique used in this study can be applied to other fields of science.

LIMITATIONS

The study was limited to the years 1967-2021, to the SCOPUS database, to four types of educational publications, to the English language, and to the keyword "game". All these features could be expanded and new features could be added in similar studies planned in the future. The articles that were scanned into the database and added in image format could not be included in the analysis because they could not be transferred into text format. In this way, more in-depth analyses can be made from different perspectives.

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- Increase in the number of game researches in the last two decades was explored.
- Transition to Serious Educational Games and Game-based Learning Terms was seen.
- Increase in the number of games developed in science and physcial education was explored.
- Insufficient number of robust and longitudinal researches was obtained.
- The key purpose of the study is to reveal the trends and changes in game in education

Credit Author Statement

Cansu Cidem EKIN: Abstract, Methodology,Result and Analysis, Writing- Reviewing and Editing **Elif Hopcan**: Abstract,Introduction, Discussion, , Writing- Reviewing and Editing **Sinan Hopcan:** Abstract,Introduction, Discussion, Writing- Reviewing and Editing