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Comparison of Gamification, Game-Based Learning, and Serious Games in Medical Education: A Scientometrics Analysis

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Abstract

Introduction: Game in education aims to enhance human motivation and performance in a given activity. Gamification experts and health researchers are still unsure about the status of progress of game for health. So, to fill in this gap, the present study aimed to analyze scientific productions to identify production trends, subject areas, countries, institutes, and authors in these three areas on gamification, game-based learning, and serious games in medical education, as well as to determine co-authorship patterns.

Methods: The present descriptive quantitative research was conducted through scientometric analysis by using co-authorship networks in gamification, game-based learning, and serious games. First, an advanced search was performed from 1990 to 2020 and the studies were retrieved from Web of sciences, on Aug 17, 2021 The plain text format of data was inputted to Microsoft Excel, CiteSpace and Gephi to analyze scientometric maps for the three domains. Subsequently, the required indicators to review co-authorship networks were obtained: Degree centrality, Betweenness centrality, Closeness centrality, Density, Clustering coefficient, collaboration index and collaboration coefficient.

Results: There were 466 documents in gamification, 155 documents in game-based learning, and 295 documents in serious games. The results indicated the rising trend of scientific publications on the three domains. US was a prolific country in all three domains. Author collaboration has remarkably increased, although the number of single-author articles is still high.

Conclusion: Due to the increasing growth of publications on these three domains, research can be continued by forming specialized groups and supporting joint publications. Also, research policy-makers should promote author collaborations on the national and international scale.

Keywords: Gamification, Game-based learning, Medical education

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Introduction

The use of games or game elements in education have a long history, dating back to the 1960s (1, 2). In the domain of education, games can be used to provide learning content (3). In contrast to traditional learning in which learners often passively acquire knowledge from teachers, games provide more engaging learning experiences, enhance the learning outcomes, provide active learning (4), and improve cognitive abilities by developing decision-making, teaching cooperation, and problem-solving skills (5). Games and game elements have been implemented at all levels of education (2). If learning through games seems appealing, games can revolutionize the core of medical education (6). Medical education has several long-established educational approaches to learning in addition to face-to-face lectures via a teacher-centered model (7).

The goal of medical education is to contribute to students' professional qualification, socialization, and sunjectification, rather than to "make them learn" (8). Since the last few dacades, a shift from traditional teaching approaches to new approaches employing media, such as online, distance, or electronic learning has been observed (9). To this end, the application of digital games in medical education has been recommended (10). When it comes to education, the literature usually refers to games as gamification, serious games (SG), and game-based learning (GBL) (11-13). The definitions of these terms may overlap or encompass one another (14). Many experts are still unsure about the differences between gamification, SG, and GBL (15). Promoting motivation and perfomance for a given task is the main goal of gamfication which is described as the employment of game design elements in a learning environment which is not specifically designed for game purposes (16). SGs are software programs having a graphical interface which contain possible interactions and information. They should also possess features that guarantee their efficiency, including rules, strategies, levels, challenges, rewards, and ongoing feedback. SGs are also defined as programs possessing learning features that alternate between educational and playful tasks (17). GBL is a learning strategy that promotes effective learning, improves the thinking process, and enhances problem-solving skills (18). Learning and behavioral modification are the primary goals of game-based learning (19). GBL utilizes a real game to transfer knowledge and skills. It possesses an independent unit with determined start, gameplay, and ending states. There is also a win state defined for learners who are engaged with the game. Although games offer a variety of educational contents in different settings, gamification only uses a few game elements. Students do not interact with the entire game from the beginning to the end; rather, they are engaged in a session that employs game elements, e.g., receiving awards for completing a problem/task, overcoming a challenge/obstacle, and getting points (15).

With such a flood of new knowledge, it is becoming increasingly difficult for a researcher to keep up with the pace of research, even in a specific area of expertise such as education (20). Moreover, gamification experts and health researchers are still unsure about the status of the references, possible areas of application, and progress of gamification for health, while being confident of these issues will help them apply the knowledge to the daily lives of learners and patients (21).

Several methodologies, such as bibliometrics, scientometrics, and co-authorship analysis, can be adopted to summarize and visualize the state of the current literature (18, 22). Quantitative analysis of publication and citation data can help assess the development, maturity, outstanding authors, conceptual and intellectual maps, and trend of a scientific community (23). Bibliometrics and scientometrics, in particular, have become prominent approaches since they deliver findings using statistics, network structures, and text analytics (15). Moreover, due to collaborations in many academic disciplines, understanding the dynamics of these networks is critical to comprehending the evolution of academic fields. While collaboration can take many forms, the most typical method for formally assessing association is to examine co-authorship relationships in scientific papers (24).

There is a considerable volume of publication on these three domains; as such, scientometrics and collaboration network analysis and plotting can provide a comprehensive view of the status of knowledge in these areas. However, in gaming, most of the previous studies do not consider gamification, GBL, and SG together, and solely focus on one or two types of games (21, 25-28). The current study can practically represent the relationships at the level of authors, journals, time intervals, keywords, etc. in the research literature of these domains. It can also offer a deep insight into the structure of an area of knowledge that has gained momentum in recent years and motivated numerous credible studies. Since no effort has been made to visualize the knowledge structure of gamification, GBL, and SG.

Methods

The present descriptive quantitative research was conducted through scientometric analysis, using co-authorship networks in gamification, GBL, and serious game. The study was conducted in four stages. First, an advanced search was performed on Aug 17, 2021 by using search operators (Boolean, parentheses, and quotation marks) for studies on gamification, GBL, and SG in medical education indexed in the Web of Science (WOS) from 1990 to 2020 and the studies were retrieved. The WOS database was chosen because it indexes the prominent journals in the field of educational games, e.g., JMIR Serious Games, IEEE Transactions on Games, and Games for Health Journal; thus, a large number of their documents can be found in this database. The researchers intended to provide a scientometric overview of these three topics, so they considered all years (1990-2020). Only research articles published from 1990 to 2020 on these three topics in medical education were included. After refining, the data were stored in TXT format (plain text in the form of lines). Selected keywords for research included: "Game and learning", "Educational games", mobile app, app$, game*, serious games, gamification, gamif*, gameplay*, videogam*, medicine, medical educat*, medical train*, medical field training, medical school*, medical Intern*, medical residen*, medical student*. In the next step, to ensure these publications' relevance to the objectives of the study, information such as year, authors, journal, type of game intended for the research, and the purpose of the research were entered in the data collection form.

In third phase, TXT data were inputted to Microsoft Excel v16.60 MacOSX, CiteSpace v 6.1.R2, and Gephi v 0.9.5 to analyze scientometric maps for the three domains. Excel was used to plot the graphs displaying the status of scientific publications in terms of time trends, journals, organizations, etc. The collected data were called by applying the appropriate thresholds and selecting the number of nodes in the CiteSpace software; then, the outputs of this software were saved and called to Gephi to plot the networks. In Gephi, the non-directional network option was selected, and the desired network was drawn by choosing the Fruchterman algorithm and Force Atlas 2. Subsequently, the co-authorship indicators were retrieved from the statistical analysis.

In final phase, the indicators required to review co-authorship networks were: Degree centrality, the simplest type of centrality, in which the value of each node is achieved by counting the number of its adjacent nods; Betweenness centrality, which indicates the importance of the node in terms of its position as well as the transmission of information in the network, 'A person located between many other nodes has the highest betweenness centrality.'; Closeness centrality, which measures the actual position and distance of a node from all other nodes in the network; Density, which shows the discreteness/continuity of a network, 'The higher the network density, the more continuous the network. A discrete network is one in which the connection between nodes is small or the number of links is lower than the number of nodes, while a continuous network is one in which the number of links is more than the number of nodes.'; and Clustering coefficient, which denotes to what extent the network nodes tend to form clusters with one another.

Finally, to examine the co-authorship status in these three domains during different years, the collaboration index (CI), collaboration coefficient (CC) of each year (19), and the average of all years were calculated by the following formula.

CI is an indicator denoting the average number of authors per year. The CI formula is

$$CI = \frac{\sum_j^k = 1j * fj}{N}$$

f_j=the number of research articles with j authors published in a specific period on a specific topic
N=the total number of research articles published in the same period on that topic
K=the total number of authors per article on a topic

CC denotes the rate of collaboration between the authors. The CC formula is

$$Cc = 1 - \frac{\sum_j^k - 1 \left(\frac{1}{j}\right) f_j}{N}$$

F=number of articles with authors
j=articles (1 author, 2 authors,3 authors, 4 authors and more than 4 authors)
N=number of articles
K=the greatest number of authors in a papers

Where the value of CC is between 0 and 1; the closer it is to 1, the greater the collaboration between the authors.

Ethical Consideration

This research was funded by Iran University of medical sciences (Grant No: 013720663) and the reference number of ethics approval obtained for the project is IR.IUMS.REC.1400.359.

Results

After searching the WoS database and recording the extracted information in the data collection

form, the retrieved documents' relevance to the topic of the study was examined. There were 466, 155, and 295 documents pertaining to gamification, GBL, and SG, respectively. The studies were analyzed in terms of years, journals, countries, organizations, and subject domains, and the 10 most frequent cases are depicted in Figure 1.

Figure 1 displays the trend of publication from 1990 to 2020 for these three domains. The first articles on gamification and SG were respectively published in 2012 and 2009. However, the first article on GBL is much older, published in 1999. This indicates the precedence of research on this concept compared to the other two domains. The growth of publications on all domains, and gamification in particular, assumed a rising trend since 2016. Although articles on GBL had been published earlier than those in the other two domains, this topic found little popularity in recent years and demonstrated a slower growth in publications.

The core journals of the three domains are depicted in Figure 2. There are many overlapping journals in gamification and SG, but the journals related to GBL are mostly active in the domain of medication and pharmacology. In SG and gamification, journals published by JMIR have received considerable attention and include the Journal of Medical Internet Research Mobile Health and University Health (JMIR mHealth and uHealth) (Impact Factor (IF)=4.3), Journal of Medical Internet Research (IF=5.03), JMIR Serious Games (IF=3.53), JMIR Medical Informatics (IF=2.58), and JMIR Research Protocols, indexed in Scopus and PubMed.

The domains were also examined in terms of the articles' countries of origin, and the results are depicted in Figure 3.

Based on Figure 3, the publications on gamification, GBL, and SG have different countries of origin. Still, in all three domains, the United States is the most prolific country, followed by the UK in the second or third rank.

The active subject domains related to gamification, GBL, and SG are presented in Figure 4. Some subjects, e.g., public environmental occupational health, healthcare science services, and education research are shared by all three domains but with varying numbers of documents. In terms of the number of documents, public environmental is the first topic in gamification compared to SG and GBL.

Figure 5 presents the prolific universities.

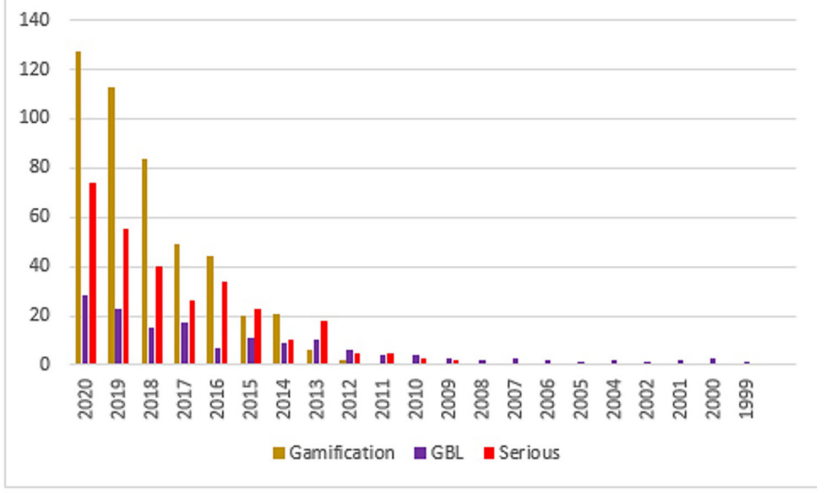

Figure 1: Trend of publication on gamification, game based learning and serious games from 1990 to 2020

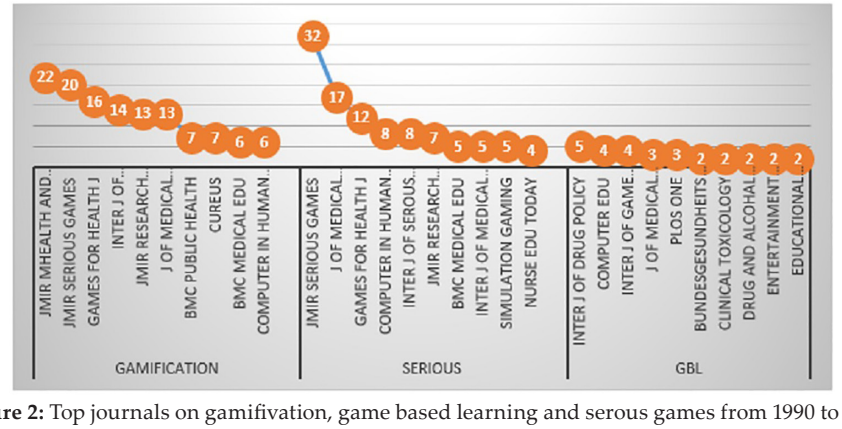

Figure 2: Top journals on gamifivation, game based learning and serous games from 1990 to 2020

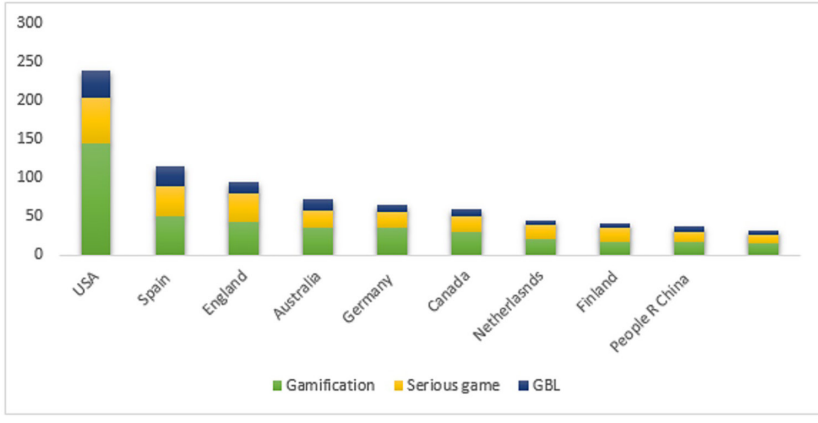

Figure 3: Prolific countries in terms of articles in gamification, game based learning and serous games from 1990 to 2020

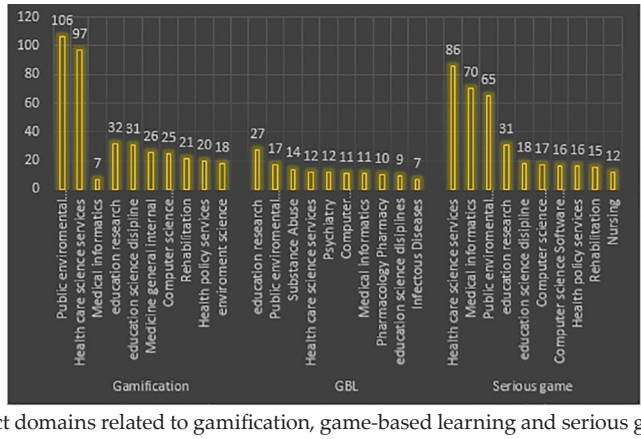

Figure 4: Active subject domains related to gamification, game-based learning and serious games from 1990 to 2020

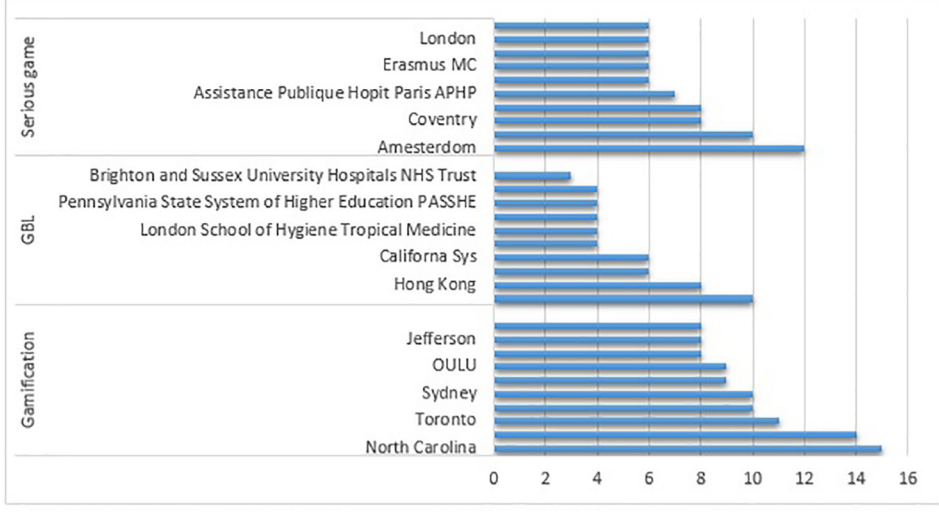

Figure 5: Universities actively publishing on gamification, game-based learning and serious games from 1990 to 2020

North Carolina, London UN, and Amsterdam universities created the greatest volume of content on gamification, GBL, and SG, respectively.

Based on what was mentioned in the Methods section, collaboration index and the collaboration coefficient for each domain are presented in Table 1.

The degree of collaboration on all three domains has markedly increased in recent years. Based on Table 1, the number of single-author articles is still high, and there are few two- or three-author articles across years. The collaboration coefficient for SG is high and satisfactory, with values near 1. The mean collaboration coefficient on gamification is lower than the other two domains. For gamification, the mean number of authors per article was the highest in 2012, 2013, and 2015. For GBL, the mean number of authors per article was the highest in 2016, and for SG, this value was the greatest in 2012 and 2010.

The co-authorship network was plotted by the software for all three domains (Figures 6-8).

Table 1: Collaboration index and collaboration coefficient for gamification, game-based learning, and serious games from 1990 to 2020

	Year	Articles in each year	Single Author	Double Author	Three Author	Four Author	>Four Author	CC	CI
Gamification	2020	127	6	14	11	20	64	0.73	3.6
	2019	113	4	11	38	20	60	0.66	4.6
	2018	84	6	10	26	14	40	0.62	4.3
	2017	49	4	9	34	6	13	0.51	4.3
	2016	44	2	11	23	7	20	0.51	5
	2015	20	2	4	15	4	5	0.45	5.8
	2014	21	4	5	10	3	8	0.42	4.5
	2013	6	0	1	7	1	4	0.35	7.8
	2012	2	0	1	2	0	1	0.45	6.5
		Total=466	28	66	166	75	215	-	
GBL	2020	28	2	5	8	4	15	0.61	4.5
	2019	23	1	1	2	4	9	0.78	3.04
	2018	15	2	0	3	2	10	0.64	4.6
	2017	17	2	2	4	3	6	0.64	3.5
	2016	7	0	0	0	3	6	0.62	6
	2015	11	0	0	0	1	4	0.90	2.1
	2014	9	1	1	0	0	4	0.75	2.5
	2013	10	0	2	0	2	3	0.79	2.7
	2012	6	1	0	0	2	1	0.72	2.3
	2011	4	0	3	0	1	0	0.57	2.5
	2010	4	0	1	0	2	1	0.70	3.7
	2009	3	0	0	0	1	1	0.85	3
	2008	2	0	0	0	0	1	0.90	2.5
	2007	3	0	1	0	0	2	0.70	4
	2006	2	1	0	0	0	0	0.50	.5
	2005	1	0	0	0	1	0	0.75	4
	2004	2	0	0	0	2	0	0.75	4
	2002	1	0	0	0	0	0	0.80	0
	2001	2	0	1	0	0	1	0.65	3.5
	2000	3	0	0	0	2	1	0.77	4.3
	1999	1	0	0	0	0	1	0.80	5
		Total=155							
Serious Game	2020	74	3	5	9	14	42	0.72	4.1
	2019	55	1	7	7	8	32	0.73	4.1
	2018	40	0	5	6	3	25	0.75	4.1
	2017	26	2	4	4	2	14	0.67	3.8
	2016	34	1	3	2	9	15	0.76	4.2
	2015	23	1	4	5	7	9	0.65	4.2
	2014	10	0	0	2	2	6	0.76	4.4
	2013	18	3	1	1	4	9	0.63	3.8
	2012	5	0	0	1	0	4	0.77	4.6
	2011	5	0	0	2	0	3	0.74	4.2
	2010	3	0	0	0	1	2	0.78	4.6
	2009	2	0	0	1	1	0	0.71	3.5
		Total=295							

CC: Collaboration Coefficient; CI: Collaboration Index

Then, a table of the co-authorship indicators for the three domains was provided.

In Figure 6-8, there are 68 nodes and 130 links, 11 nodes and 10 links, and 67 nodes and 136 links for the co-authorship networks of gamification, GBL, and SG, respectively. The greatest relationship among authors is shown by larger circles while the limited links having small size represent the co-authorship network of GBL. The highest degree of centrality belongs to Weatherburn, Hickson, and Bourne whereas there is a more extended co-authorship network with higher links in Gamification and SG. Serious game also shows higher links. Regarding the gamification network, the highest degree is obeserved in Hilbert, Steier, and Rareshide, and in

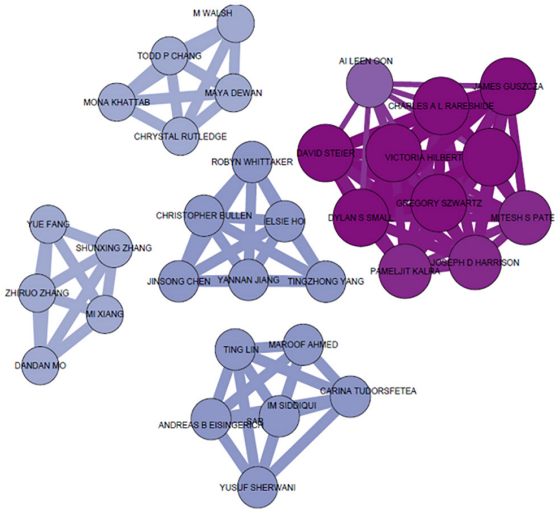

Figure 6: Co.authorship network for gamification from 2012-2020

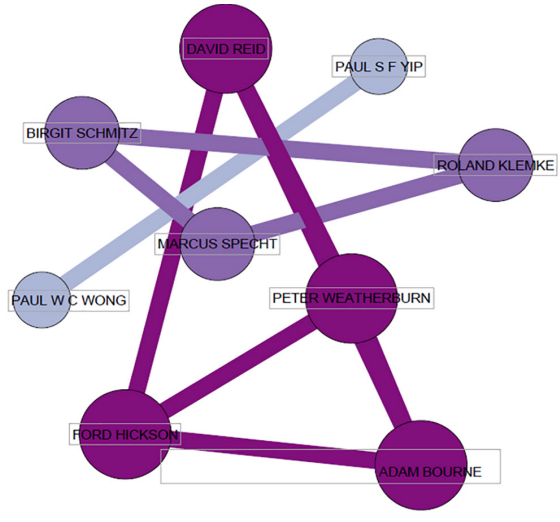

Figure 7: Co authorship network for game based learning from 1990-2020

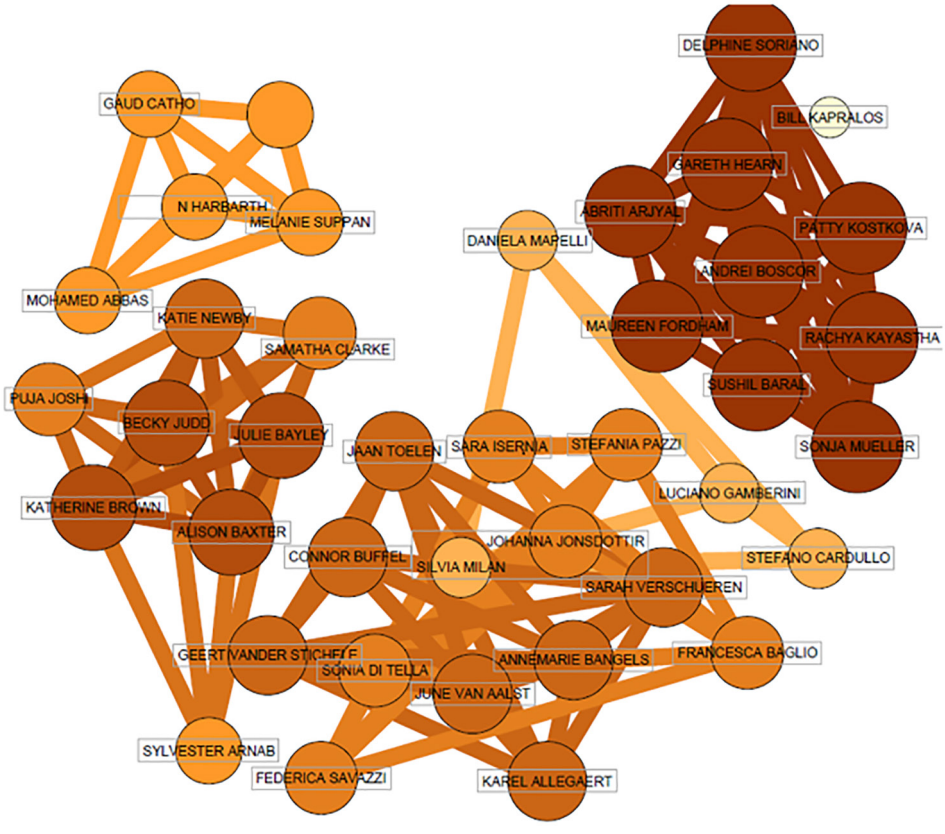

Figure 8: Co authorship network for derious game from 2009-2020

SG, Soriano, Arjyal, and Fordham. Considering network density or structure, all three networks are continuous as the number of links is higher than the number of nodes.

Based on the indicators explained in Materials and Methods, Table 2 is presented for the three domains by determining the authors with the highest indicators.

The same authors are observed in all indicators for gamification and GBL. For instance, in GBL, Hickson has the greatest relationship with the neighbors in terms of degree centrality; has the highest status in terms of betweenness centrality and links other authors; is surrounded by fewer mediators in terms of closeness centrality and receives information more quickly. Serious game and GBL have a clustering coefficient of 1, indicating their high tendency to form clusters. In SG, the number of clusters is considerable; but in gamification, the value is near 1, showing the lower tendency of this network.

Table 2: Co-authorship indicators for gamification, game-based learning, and serious games from 1990 to 2020

Fields	Authors	Degree Centrality	Betweenness Centrality		Clossness Centrality		Clustering Coefficient
Gamification	David Steier	0.00	0.42		1		0.93
	Gregory Szwartz	0.00	0.42		1		
	Charles AL Rareshide	0.00	0.42		1		
	James Guszcza	0.00	0.42		1		
	Victoria Hilbert	0.00	0.42		1		
GBL	Ford Hickson	3	0		1		1
	Adam Bourne	3	0		1		
	David Reid	3	0		1		
	Peter Weatherburn	3	0		1		
	Roland Klemke	2	0		1		
Serious Game	Delphine Soriano	8	Maurits Graafland	2	Maurits Graafland	1	1
	Abriti Arjyal	8	Ecky Judd	0.95	Ecky Judd	1	
	Maureen Fordham	8	Lison Baxter	0.95	Lison Baxter	1	
	Gareth Hearn	8	Atherine Brown	0.95	Atherine Brown	1	
	Sonja Mueller	8	Ulie Bayley	0.95	Ulie Bayley	1	

Discussion

The present scientometric study investigated the publications on gamification (466 documents), GBL (155 documents), and SG (295 documents). No scientometric study had compared these three domains in medical education before, and studies had investigated each domain separately. The results indicated the rising trend of scientific publications on the three domains. The entry of z-generation learners (born from the mid-1990s to the early 2000s) whose birth coincided with the expansion of the World Wide Web (24) to universities may have affected the use of educational games in educational processes, thereby extending research and publications. The results indicated a rising trend of articles on gamification since 2016; similarly, recent studies confirm that the application of gamification to engage and motivate target learners has had a rising trend with successful outcomes in recent years (22, 25-28). A study examining gamification publications in Google Scholar, Scopus, and Web of Science reported that the number of publications is increasing, and >60% of them are Scopus-indexed . Evidence suggests that educational gamification in medical education promotes players' cognitive, psychomotor, and emotional competencies (28). According to experts, gamification is a suitable tool for the professional promotion of those working in medical professions and provides an opportunity for interdisciplinary education (29). The same increasing trend was reported in another study focusing on SG. According to the researcher, up to 2010, the trend of articles on SG greatly fluctuated, with two articles on average published annually; however, from 2011 to 2019, this value significantly grew and reached 28 documents per annum (2, 30). The literature confirms the rising trend of articles on SG in the education of various domains, including health and medical sciences (1, 31). The articles on gamification have surpassed those on GBL. The greater popularity of gamification may be due to the differences between these two topics; gamification uses more extensive game elements, while GBL is principally focused on learning objective development (32, 33).

Most of the journals publishing on GBL belonged to the domain of medication and pharmacology, whereas journals published by JMIR received more attention in terms of gamification and SG. Pharmacology related topics may be tiresome as the names of hundreds of drugs, indications, and side-effects should be memorized; therefore, maintaining the learners' motivation and concentration is always challenging for pharmacology professors (34). Compared to other medical disciplines, pharmacology has a greater need for learner-centered and active learning methods that make learning more interesting and lead to optimal learning outcomes (35). The use of gamified pharmacology in GBL with specified educational goals as an active and novel approach is daily increasing; consequently, most articles related to this subject are published in specialized pharmacology journals. The same approach to gamification and SG for ensuring active learning is observed in JMIR journals that cover a wider range of medical sciences. According to Swacha, <3% of gamification researchers publish only in three journals. Swacha believes that research on gamification in education is often a short-term activity, not a scientific specialty (16).

In the study on prolific countries in terms of

gamification, game-based learning, and SG, the results indicated the undisputed superiority of the US in all three domains. Similarly, the literature reports the US as the leading country in research on gamification (16, 36), SG (2, 30), GBL (37), and even video games (38) The US is followed by European countries in all three domains. Still, Canada in all three do-mains, China in gamification and GBL, and Brazil in SG have a notable status among the top 10 countries. Even though the US and some European countries are the leading countries in research on educational games, the interest in novel approaches to educational games is globally expanding (31, 36). The prolific universities in terms of research on gamification, GBL, and SG were North Carolina (USA), London UN (UK), and Amsterdam (the Netherlands) universities.

Consistent with similar studies (1, 16, 22, 30), subjects such as public environmental occupational health, healthcare science services, and education research are dominant in all three domains, but with a varying number of documents. A significant number of publications focused on specialized health and medical sciences, and the three domains of gamification, GBL, and SG were regarded as an educational technology context for other disciplines.

In recent years, author collaboration has remarkably increased in all three domains, although the number of single-author articles is still high. Since research on these topics should adopt an interdisciplinary (39) and multidisciplinary (40) approach, multi-author research and articles will be more effective. The collaboration coefficient for SG is high, with values near 1.

Based on co-authorship network analysis, collaboration was limited in GBL but high in gamification and SG. This is not consistent with the findings of Lopez et al., Trinidad et al., and Swacha et al. (16, 21, 22). Swacha conducted a gamification scientometric study on three databases (Web of Science, Scopus, and Google Scholar); eventually, the co-authorship network was plotted based on the publications in Scopus alone. Moreover, Lopez et al. and Trinidad et al. focused on all the publications related to gamification. Nevertheless, the present study was conducted on the Web of Science and examined only publications related to gamification, GBL, and SG in medical education. Taking the differences between these studies into account, one can conclude that their results indicate few co-authorship networks in gamification, with some co-authorship collaborations in one cluster but little collaboration between clusters and subjects. Moreover, more prolific authors had less collaboration, whereas less prolific authors had more collaboration with other authors. The analysis of the results of the clustering coefficient shows that, contrary to gamification, GBL and SG have a greater tendency to form clusters.

Conclusion

In a world where technology is changing everything, education should also evolve. The use of electronic tools in education is one of the potentials and capacities of technology in advancing educational goals. Technology helps create new opportunities for more effective education. Based on the findings of this study, numerous researchers have paid great attention to different aspects of using gamification, GBL, and SG in medical education. The periodical assessment of this research domain is of utmost importance. Herein, by using scientometric analysis, different dimensions of three newly emerging educational domains (gamification, GBL, and SG) in medical education were analyzed and compared. The findings of this study can provide deep insights into these domains, e.g., the rate of publications over time, prolific countries, core journals, involved subject domains, and active organizations. Co-authorship is a major factor promoting scientific publications and leading to development and progress; thus, in addition to displaying the scientometric status in gamification, GBL, and SG, this study delineated the co-authorship status of authors, subjects, countries, and organizations, and presented important co-authorship indicators. Due to the increasing growth of publications on these three domains, research can be continued by forming specialized groups and supporting joint publications. With regard to the importance of co-authorship in scientific publications, and researchers' tendency to collaborate, research policy-makers should promote such collaborations on the national and international scale and provide adequate budget and facilities for this purpose.

Authors' contribution

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Sh.A.Z, M.Z, S.H.B, SHM. The first draft of the manuscript was written by Sh.A.Z and M.A and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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