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Review Article

Gamification in education: A citation network analysis using CitNetExplorer

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ABSTRACT

Gaming is becoming a popular method of engaging students in learning processes across all levels of the educational community. The effective integration of gaming activities into course curricula has the potential to enhance student learning, motivation, and knowledge acquisition in a range of disciplines. However, gamification of education is not without its opponents, with many educators concerned about the negative impacts of game use on effective learning. This study enhances our understanding of contemporary practices related to the areas, usage and characteristics of gamification in education. It is of particular relevance to educational institutions with a focus on developing innovative teaching methods and curricula that utilize gamification techniques in a multi-disciplinary, cross-national context across all stages of formal learning. Through the use of bibliometric analysis techniques, our study of the citation relations of 3,617 publications identified ten prominent themes dominated by gamification: mobile gaming, physical education, health and medicine, business, learning performance, programming and computing, English language, teacher adoption, primary & secondary education, and mathematics. Clear evidence of increased student motivation to learn and improved course results were evident in the examined literature. This study will benefit *serious* game designers, educators, and educational institutions to develop more inclusive and engaging pedagogies that exploit the ubiquitous availability of gaming technologies for inclusion in more traditional course delivery methods.

Keywords: learning strategies, information and communication technology, teaching practices, knowledge creation, gamification, bibliometric analysis

INTRODUCTION

Principles and Purpose of Gamification

Educators often employ gamification to facilitate the acquisition of knowledge and skills in a range of subject areas. Gamification can be described as the deployment of game-based strategies to engage users in problem-solving that can be used in educational settings to improve student motivation to engage in learning (Nah et al., 2013). Other terms associated with gamification include *game-inspired design*–the use of game-related ideas and ways of thinking in curriculum design that does not explicitly use game-based activities, *serious games*–games that are created for a specific educational purpose rather than for leisure, and *simulations*–games that recreate real-world phenomena (Kiryakova et al., 2014). The proper deployment of games in an educational setting requires the availability of appropriate technological infrastructure and an instructional framework that can accommodate gaming activities (Dicheva et al., 2015). Measurement and data collection are also important considerations when designing gaming frameworks, as discovered in Mora et al.'s (2017) systematic review of gamification design characteristics. For gamification to be an effective pedagogical tool, the underlying gaming activities must have a sound educational base. Nah et al. (2013) identified five main principles of game design that contribute to overall effectiveness: structured goal orientation, student achievement is easily conveyed, reward structures exist that reinforce positive behavior and performance, creation of a competitive environment that promotes student engagement, and the game is actually fun to play. Ultimately, the purpose of gamification from a design perspective is to change human behavior to achieve a specific outcome that translates (in an educational context) to a positive enhancement of student learning (Landers et al., 2018).

Strengths and Weaknesses of Gamification in Education

There are many benefits of incorporating game-based activities into educational activities. In a study of digital game-based learning and serious games in education, Anastasiadis et al. (2018) found several benefits of gamification to student learning. These included improved digital literacy and cognitive growth, soft skill development, the development of sound decision-making and problem-solving skills, better collaboration and communication with peers, skill development in a competitive environment, improved self-esteem, and reinforcement of learning progress through feedback and reward mechanisms inherent in well-designed serious games. Another study of secondary and tertiary education students studying supply chain management found that the provision of workshops incorporating gamification elements significantly improved student knowledge retention of important concepts relevant to the subject area (Putz et al., 2020). Gamification in learning can also have an impact on student motivation. In van Roy and Zaman's (2018) study of the motivational effects of introducing gaming into a course to assist students in their English writing, it was found that student motivation tended to improve over time but was dependent on the individual preferences and characteristics of students. Gaming in learning environments can also foster the development of collaborative skills. For example, in multiplayer situations, games can promote social interaction and the development of teamwork skills (Christians, 2018). However, some researchers suggest that integrating games into course delivery is not without its drawbacks. The cost of acquiring technology and the availability of technical support to service gaming systems can be a substantial barrier to the use of gamification in some educational contexts (Papadakis, 2018).

Ruggiero's (2013) survey-based study of teacher opinions on the use of video games in the classroom revealed that many teachers felt that games should not be used as the main instructional activity. They further assert that teachers wishing to deploy more complex games needed to be experienced players themselves in order to evaluate the game's effectiveness in specific learning contexts. Finally, it can be difficult for teachers to assess what students have collectively learned from a game because of differences in individual student gaming behavior, leading to non-standard learning outcomes for different students (Cojocariu & Boghian, 2014).

Knowledge Domains Utilizing Gaming

There are many examples of knowledge areas in education that use structured games to facilitate learning. Programming and Information Technology-related skill development is particularly amenable to gamification. For example, a study of 79 5th graders investigated the use of an adaptive educational game called *auto thinking* to improve computational thinking (Hooshyar et al., 2021a). Their study found that not only were there improvements in student computational thinking, but general interest levels, satisfaction, and technology acceptance were also advanced through the integration of this game into class activities. Mathematics and science are also knowledge areas that are conducive to gamification. Yong et al. (2020) explored the use of computer games in mathematics education and found that by applying gaming principles to teaching practice, course delivery became more process-focused and problem-based. This promoted an attitude and acceptance by students of *learning from mistakes*.

A systematic review of technology-infused gamification studies in science education also found benefits in adopting this approach - particularly in relation to improved motivation leading to subsequent improvements in assessment results (Loganathan et al., 2019). Another interesting knowledge domain represented by gamification is nursing education. Kinder and Kurz (2018) explored the use of an online game called *kahoot.it* to create trivia-style questions for shared use. By comparing a group of students who used *kahoot.it* with a control group that did not, the study found significant differences in the final examination scores between nursing students who played the game and those who did not.

Study Purpose

The purpose of this study and central research question is to “identify the areas, usage and characteristics of gamification in education”. The study was motivated by a need to explore how gaming technology impacts the design and delivery of education across a diversity of knowledge domains. The study builds on the work of Kalogiannakis et al. (2021), who reviewed available literature on the state of gamification in science education, Zourmpakis et al.’s (2022) study of elementary teacher’s use of adaptive gamification in science education, and a study exploring the use of contemporary gamification techniques by teachers in a range of disciplines (Logothetis et al., 2022). To fulfil the aim, this paper adopts a bibliometric approach to identify and describe gamification usage in education with respect to knowledge domains, education level (primary, secondary, tertiary), and more general applications. No prior study has provided a bibliometric analysis of these different aspects using our chosen methodology and tools. The following section describes the bibliometric-based methodology adopted in this paper.

METHODOLOGY

Bibliometric analysis involves the application of statistical methods to discover tendencies within a research problem that can lead to the identification of emerging themes within a discipline (Rey-Martí et al., 2016). Many bibliometric tools are available to visualize the results of bibliometric analyses, including Bibexcel, Biblioshiny, BiblioMaps, CiteSpace, CitNetExplorer, SciMat, SCiTool, and VOSviewer (Moral-Muñoz et al., 2020). CitNetExplorer (van Eck & Waltman, 2014) is the open-source bibliometric tool selected for this study because of its user-friendly interface and successful application in prior studies (Kiryakova et al., 2014; Sjöberg et al., 2020; Wu et al., 2016). This tool is related to VOSviewer but focuses on the analysis of publications at an individual citation-connection level rather than VOSviewer, which examines publications at an aggregate level (Swacha, 2021; van Eck & Waltman, 2017). A full description of the CitNetExplorer system and associated methodology can be found here: https://www.citnetexplorer.nl/getting-started. This tool analyses citation networks inherent in individual publication connections that are derived from established databases of publications such as Scopus, Web of Science (WOS), and Google Scholar. The database extraction techniques employed in this study are outlined in the next section.

Web of Science Data Extraction

CitNetExplorer is designed to be compatible with the text output of WOS. Therefore, this database was chosen to conduct a broad search of publications related to gamification because the output can be easily imported into the CitNetExplorer environment. The search string applied to the WOS search was: (TI=(gamification OR game)) AND TI=(education OR learning OR school OR university or college) AND TS=(technology OR software OR program OR application). The substring “technology OR software OR program OR application” was included to retain a contemporary focus. The search was further refined to include only published journal articles and conference proceedings. Early access documents that have not yet been published were omitted from the search because the extracted records are not compatible with the CitNetExplorer system. The TI designator refers to the title field in the database, while TS includes the fields: title, abstract, author keywords, and keywords plus. By default, WOS applies stemming (Clarivate, 2021b) and lemmatization (Clarivate, 2021a) to all search strings unless an exact search is specified. Stemming removes suffixes from words, while lemmatization reduces the need to use wild cards and variant spellings of key search terms. A total of 3,617 records were returned from this search. **Figure 1** depicts the parameters used in the WOS query entry screen.

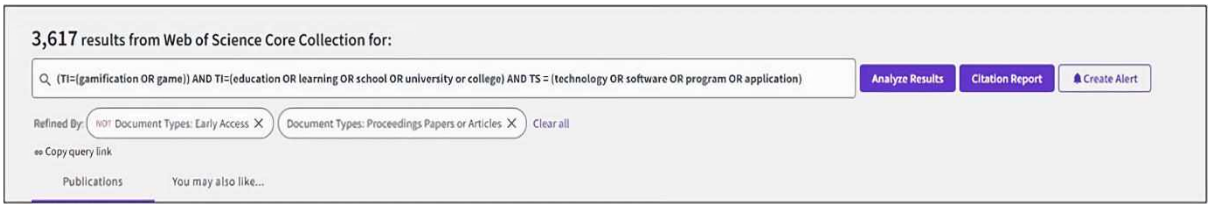

Figure 1. Web of Science search string (Source: Authors, using Web of Science platform)

The search results were exported from WOS as *Full Record and Cited References* in plain text format. As WOS limits each text file to a maximum of 500 records, it was necessary to create eight separate text files to export the 3,617 records. These records were then imported into CitNetExplorer and saved in a format compatible with the software environment: a publications file and a citations file. CitNetExplorer could now be used to explore citation relations between the extracted records. Supplementary file A and supplementary file B contain a copy of these records in *CtiNetExplorer* format: see: https://figshare.com/s/f11888d907c2f3fcec79.

RESULTS

The 3,617 publication records imported into CitNetExplorer shared 3,117 citation links between them. The time period of the publications was between 1990 and 2022. Each publication is assigned a citation score based on the number of links established with other publications. Citation scores can be internal (referring to the current network) or external (based on actual links within a bibliographic dataset) (van Eck & Waltman, 2014). It is not possible to display a graphic representation of all 3617 articles, so the display was adjusted to present the top 40 publications in terms of citation scores, as displayed in **Figure 2**.

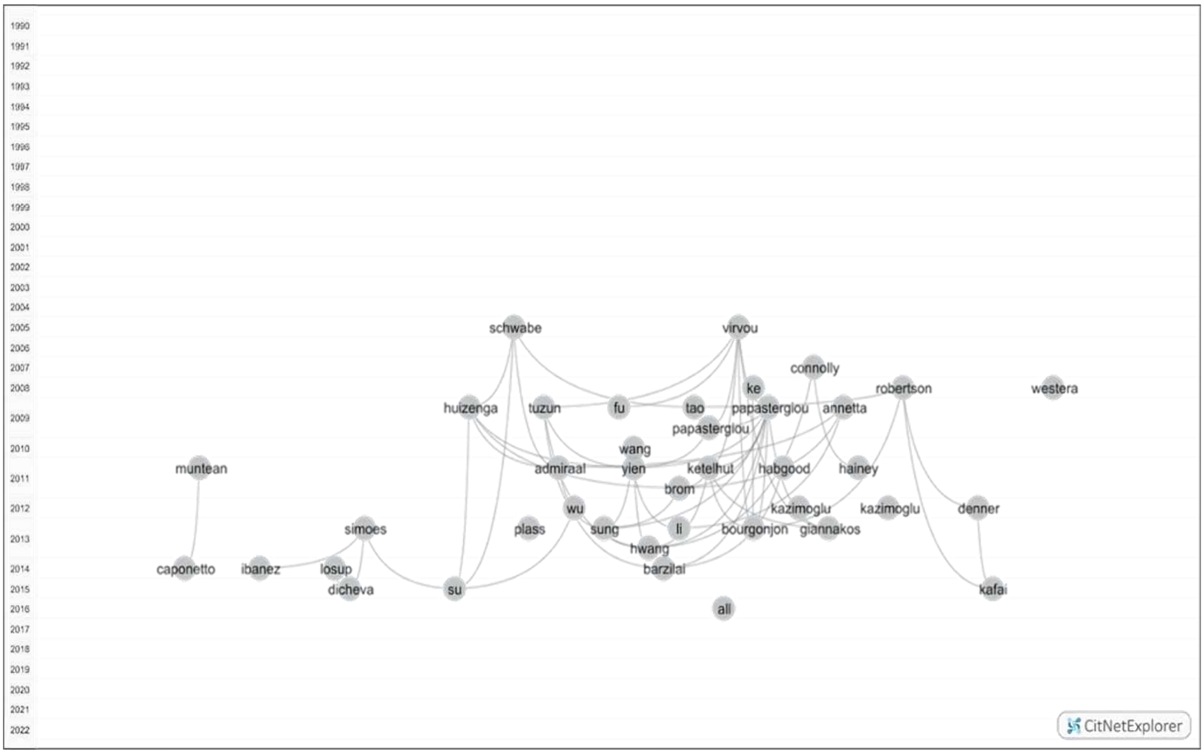

Figure 2. Top-40 publications in terms of citation links (Source: Authors, using CitNetExplorer software)

Each bubble is labelled with the author's last name and positioned vertically on the Y-axis according to its year of publication. The position of each bubble on the X-axis indicates the article's proximity to other publications, and the lines between bubbles represent the existence of citation links between publications (Healy et al., 2020). Next, the articles were segmented into clusters using CitNetExplorer's clustering tool. This tool assigns articles to clusters (also referred to as groups in CitNetExplorer software) based on their relativeness to other articles in the network (van Eck & Waltman, 2014). The tool requires the adjustment of two parameters to determine the number and size of each cluster. The first parameter, resolution, influences the number of clusters, while the second parameter, minimum cluster size, restricts the generation of each cluster to a minimum number of articles. There are no *one-size-fits-all* settings for these parameters, as each situation is different and requires the researcher to explore multiple clustering options until a satisfactory solution is discovered. After several iterations, the resolution parameter of 1.00 and minimum cluster size of 50 were chosen to generate six article clusters. Smaller clusters were not merged in the solution. This resulted in the generation of six clusters containing 1,330 articles.

The remaining 2,287 items were excluded from further analysis because they did not meet the minimum size requirement to be included in a cluster. CitNetExplorer was then configured to display the top 100 articles in terms of citation score to create an image that included representation from all six clusters. Six articles were removed from the display as they were not associated with any cluster. The remaining 94 articles are displayed in **Figure 3**.

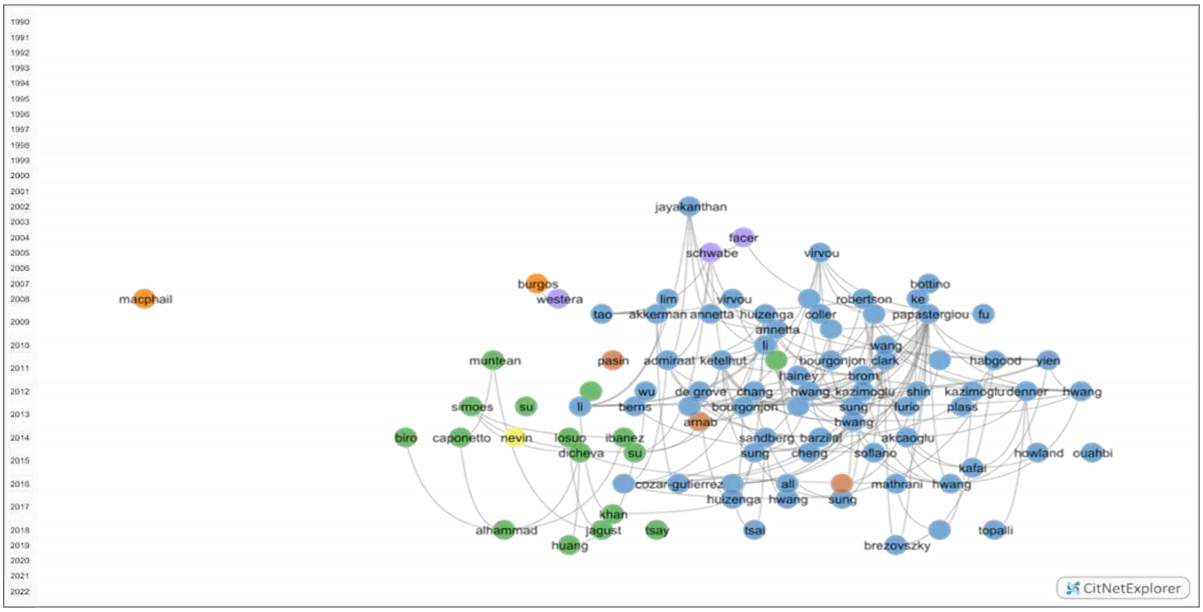

Figure 3. Level 1 six-cluster citation network of the top 94 articles. The number of articles allocated to each cluster are ●group 1-785, ●group 2-314, ●group 3-66, ●group 4-61, ●group 5-54, ●group 6-50 (Source: Authors, using CitNetExplorer software)

The clustering tool was further applied to group 1 and group 2 because of the large number of articles in these clusters. These clustering solutions are designated as level 2 because they are applied to articles derived from a parent cluster. The clustered solution for group 1 yielded eight new sub-clusters (resolution parameter=1.00 and minimum clustering size=50). The results of the top 81 articles in terms of citation scores are displayed in **Figure 4**.

The same procedure was applied to group 2 using the clustering parameters: resolution=1.00 and minimum cluster size=30. **Figure 5** displays the top 100 articles in these sub-clusters.

The level one groups 3 to 6 (shown in **Figure 3**) and level 2 sub-groups 1 and 2 (**Figure 4** and **Figure 5**) were further refined by extracting the core publications in each cluster. Core publications in CitNetExplorer refer to articles that have a minimum number of incoming or outcoming citation links with other core publications and is one measure of the significance of a publication in a citation network (van Eck & Waltman, 2014). By process of trial and error, the minimum number of citation links was adjusted until the maximum value that could generate a solution was identified. This value differed depending on the cluster examined. After examining the publications in each set of 16 core publications, 10 core clusters were found to have unique themes, as shown in **Table 1**. Articles in a cluster not associated with a theme were omitted from further analysis. The last column in **Table 1** categorizes these themes according to their focus and serves to highlight some of the differences and similarities between each cluster (or group). For example, the theme focus, *subject area*, indicates that the articles in the cluster were related to the application of gamification to specific knowledge domains, while *gaming characteristics* refers to articles that were more concerned with the characteristics of gamification in education in a more general sense.

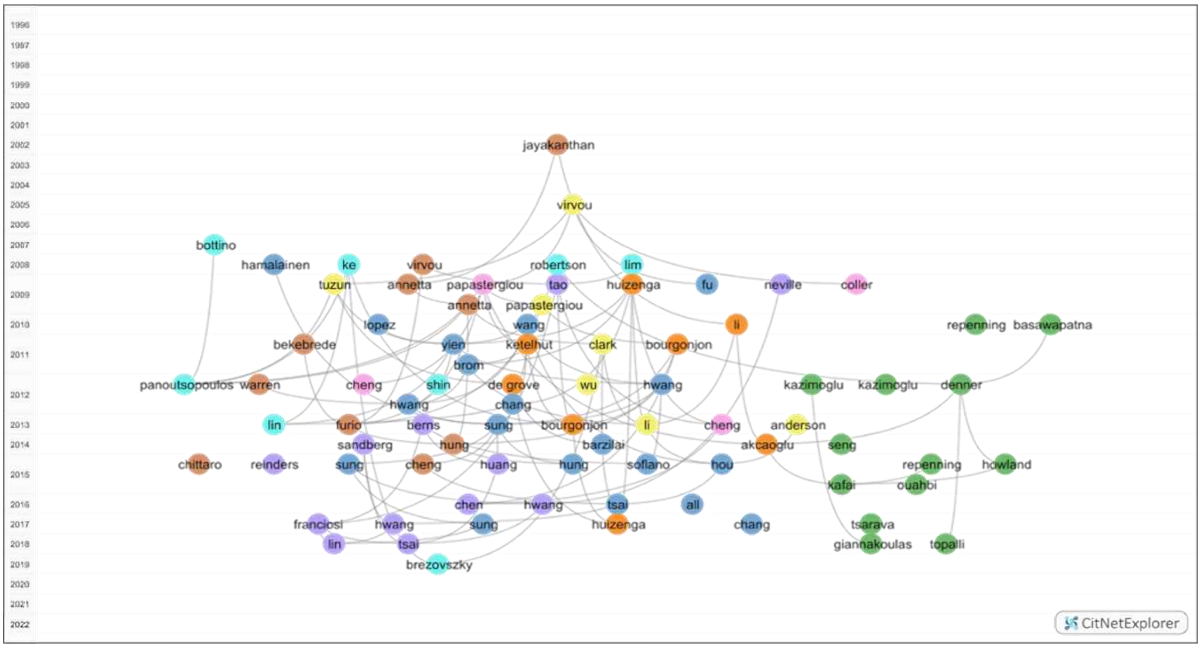

Figure 4. Level 2 (derived from level 1, group 1) clustering solution for top-81 articles in terms of citation score. The number of articles allocated to each cluster are ●sub-group 1-99, ●sub-group 2-94, ●sub-group 3-72, ●sub-group 4-65, ●sub-group 5-63, ●sub-group 6-62, ●sub-group 7-60, ●sub-group 8-57 (Source: Authors, using CitNetExplorer software)

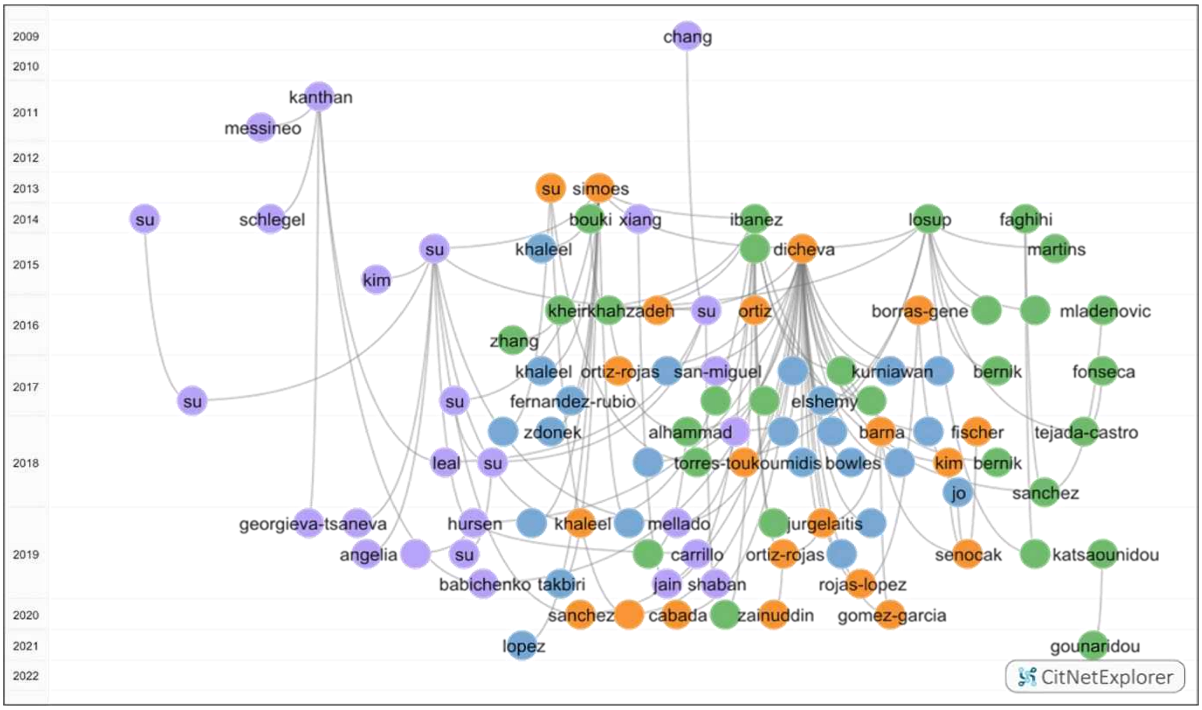

Figure 5. Level 2 (derived from level 1, group 2) clustering solution for top-100 articles in terms of citation score. The number of articles allocated to each cluster are ●sub-group 1-35, ●sub-group 2-37, ●sub-group 3-32, ●sub-group 4-32 (Source: Authors, using CitNetExplorer software)

Table 1. Themes associated with core publications of clustered solutions

Group	Theme	Number of relevant publications	Theme focus
Level 1			
Cluster 3	Mobile gaming	5	Gaming characteristics
Cluster 4	Physical education	5	Subject area
Cluster 5	Health and medicine	25	Subject area
Cluster 6	Business	8	Subject area
Level 2 cluster 1			
Sub-cluster 1	Learning performance	10	Gaming characteristics
Sub-cluster 2	Programming and computing	24	Subject area
Sub-cluster 3	English language	13	Subject area
Sub-cluster 4	Teacher adoption	5	Gaming characteristics
Sub-cluster 5	No unique theme	NA	
Sub-cluster 6	Primary &secondary schools	13	Gaming characteristics
Sub-cluster 7	No unique theme	NA	
Sub-cluster 8	Mathematics	4	Subject area
Level 2 cluster 2	No unique themes in all four clusters	NA	

Figure 6 displays the distribution of the top five core publications in each theme. Items in grey color denote intermediate publications between core publications. They have been included to display linkages between themes that are not directly connected via core publications assigned to a thematic cluster. The earliest study in the network is by Facer et al. (2004) on *mobile gaming* which is connected via citation pathways to all 10 themes in this core network. The articles by Ke (2008), MacPhail et al. (2008), and Virvou and Katsionis (2008) are the next earliest core publications in this citation network to represent their respective themes (*primary & secondary schools*, *mathematics*, and *physical education*). This is followed in 2010 by Kron et al. and Wang and Chen, respectively representing the themes: *performance related* and *health and medicine*, Ketelhut and Schifter (2011) and Pasin and Giroux (2011) (*teacher adoption of gaming* and *business*), Denner et al. (2012) on the theme of *programming and computing,* and Sandberg et al.'s *English language* related paper in 2014. The 10 unconnected core publications towards the right of **Figure 6** are related to other items in the network via non-core publications that could not be displayed in this diagram because of their low citation scores. The next section presents an analysis of the publications on each theme.

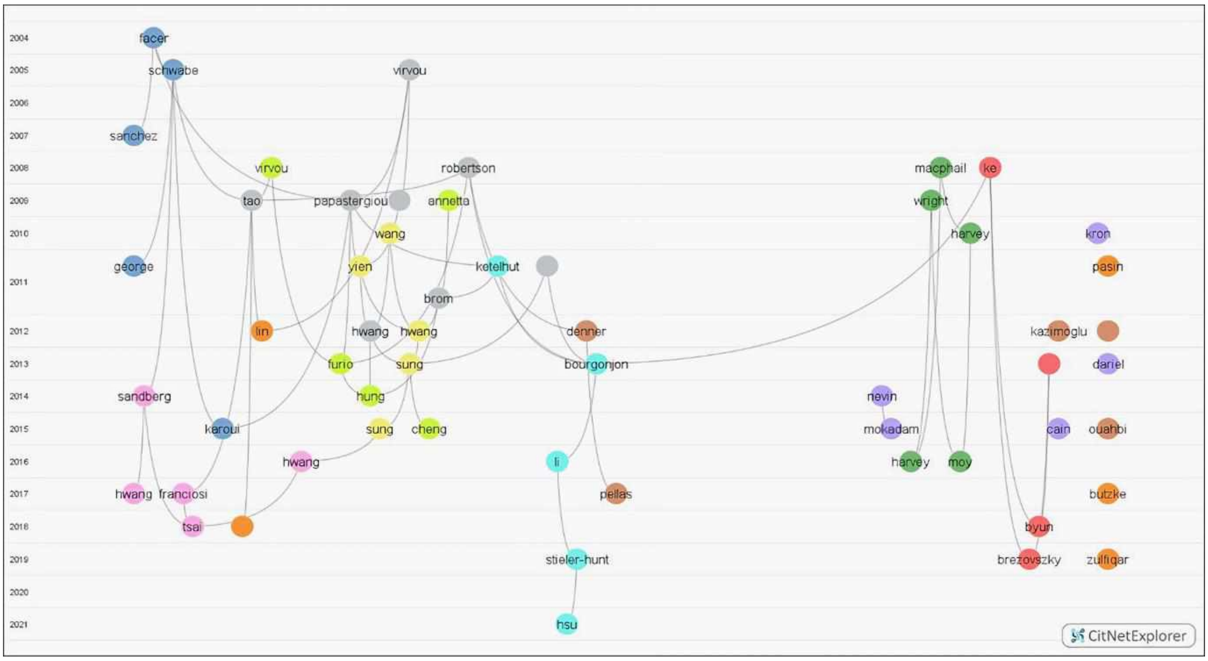

Figure 6. Top-5 core articles in each theme in terms of citation score. Legend: ●mobile gaming, ●physical education, ●health and medicine, ●business, ●learning performance, ●programming and computing, ● English language, ●teacher adoption, ●primary and secondary education, ●mathematics (only four core publications identified) (Source: Authors, using CitNetExplorer software)

DISCUSSION

This section provides an overview of the core publications identified in each of the 10 themes presented in **Table 1** and **Figure 6**. The full details of these publications are contained in supplementary file C (https://figshare.com/s/f11888d907c2f3fcec79).

Mobile Gaming–Level 1 Cluster 3

The central theme of these articles concerns mobile gaming. Two of the papers were studies on the general benefits of integrating mobile gaming into learning strategies for students. The first article, a French study on mobility in serious games (George & Serna, 2011), explored how mobile technologies favor situated and collaborative learning. Two important constraints on the effectiveness of mobile technologies in knowledge acquisition are the complexity and time-consuming development of mobile games, and the effectiveness of the teacher's delivery of these games in the classroom. The second article (Karoui et al., 2015) explored common features that contribute to mobile learning game success: location based-learning, learning autonomy, role-playing pedagogy, collaborative learning, and innovative digital tools. The paper also highlighted potential risks of mobile learning games, including distraction risks and managing individual players' progress. The other papers had a particular subject focus. The article by Facer et al. (2004) looked at the challenges and benefits of using mobile gaming pedagogies to enrich a conceptual understanding of animal behavior in children. Part of the study involved learners adopting the persona of a specific animal in a simulation that aimed to give them an appreciation of issues confronting animals in the wild. Science education and games within mobile learning environments that contribute to the development of scientific concepts were explored in Sánchez et al.'s (2007) paper. In their study, they used a mobile game called evolution as a vehicle to facilitate high school students' understanding of evolution concepts. The authors conclude that the game also contributed to the development of general problem-solving skills that could be applied to other knowledge domains. The last paper by Schwabe and Göth (2005) looks at the design characteristics of mobile designs and their impact on learning motivation in university students. The researchers conclude that students appreciated mixed reality gaming features where participant activities are represented in a digital space and acted out physically.

Physical Education–Level 1 Cluster 4

This theme includes articles related to gamification in physical education. Articles in this theme address approaches to delivering effective learning outcomes that adopt structured games. Interestingly, these publications were captured in the articles retrieved by the WOS search string even though they were not technology focused. Four articles (Harvey et al., 2010; Harvey & Pill, 2016; MacPhail et al., 2008; Wright et al., 2009) examined the application of the tactical games for understanding model (TGFU) to student mastery of physical education concepts. TGFU focuses on skill acquisition in the context of structured game-play, where students learn both the game's tactics and strategies and develop useful skills that are relevant to the game. The article by Moy et al. (2016) explored the issue of overcoming cultural assimilation issues in physical education programs by experimenting with alternate pedagogical approaches to delivering game-based training.

Health and Medicine–Level 1 Cluster 5

The central theme of these articles covers health and medical gaming. Articles in this cluster addressed health and medicine-related topics. The largest number of health-related publications were in the field of nursing. The eight nursing-related publications covered the following issues: adopting a serous gaming strategy to develop nurses teaching techniques for delivering training on effective inhaler use (Chee et al., 2019), the use of a 3D gaming platform to enhance the engagement of nursing students with course curricula (Gallegos et al., 2017), enhancing communication competence through the use of 3D games (Hara et al., 2021), establishing processes for developing serious games for use in nursing education (Johnsen et al., 2018), the application of game simulation software to combine knowledge and skill development in nursing with commonly accepted game-playing principles (Koivisto et al., 2017), the identification of sound principles of design for the development of simulation games that can develop clinical reasoning skills (Koivisto et al., 2018), an investigation of the effectiveness of game-based teaching compared to scenario simulation in developing a better understanding of disaster nursing (Ma et al., 2021), and an assessment of the potential of serious games to enhance learner acquisition of nursing concepts (Petit dit Dariel et al., 2013). The next largest genre of articles (five in total) explored the use of gaming in medical education in a general sense. These articles covered the following three topics: benefits and pitfalls of incorporating gaming into medical education (López-Jiménez et al., 2021; Maheu-Cadotte et al., 2021; Nevin et al., 2014), student attitudes towards gaming (Kron et al., 2010), and creating a framework to design and build effective games to support medical-related education (Olszewski & Wolbrink, 2017). There were three papers focusing on pharmacy-related issues. Lee et al.'s (2018) study of online games to engage pharmacy students found that games effectively complement the teaching of pharmacy in a blended learning environment. Kayyali et al. (2021) looked at the effectiveness of the serious game "DOSE" to improve the navigation proficiency of pharmacy and nursing students accessing the British national formulary – a reference source for standard medicines in the UK. The other pharmacy-related paper found that the use of serious games in pharmacy education is most effective when opportunities for employing this learning approach are identified "on the fly" as situations present themselves rather than formerly integrating the use of serious gaming as an integral part of the curriculum (Cain & Piascik, 2015). Radiology was the next most prevalent *specific* knowledge domain, with two papers (Awan et al., 2019; Winkel et al., 2020) exploring the contribution of gaming activities to the development of diagnostic competencies in a fun-enabled environment. The remaining papers focused on the application of gamification to distinct medicine-related specializations: ultrasound (Liteplo et al., 2018), insulin therapy (Diehl et al., 2017), cardiology (Kerfoot et al., 2014), dementia (Maskeliūnas et al., 2019), physiotherapy (Shahmoradi et al., 2020), and Diabetes (Talley et al., 2019).

Business–Level 1 Cluster 6

The central theme of these articles is gaming in the business discipline. Articles examining the role of business simulation games in facilitating general business knowledge acquisition dominated this theme. Five publications investigated the effectiveness of business simulation games from a student perspective on business-related knowledge and skill acquisition (Butzke & Alberton, 2017; Hernández-Lara & Serradell-López, 2018; Lin & Tu, 2012; Schmitt et al., 2021; Zulfiqar et al., 2019). The remaining three publications explored aspects of gamification in more specific business disciplines. Devitt et al.'s (2015) paper explored the use of serious games in developing marketing-related cognitive skills and found that students had a positive experience applying marketing theory to decision-making processes embedded in the game's execution. The paper on simulation games used in operations management concluded that simulation tools were more effective than traditional teaching methods for developing higher-order decision-making skills required for dealing with complex problems in operations management (Pasin & Giroux, 2011). Finally, Oliveira and Melo's (2020) study of the use of an electronic simulation of the Brazilian stock market found that this approach delivered significant benefits to student acquisition of skills and knowledge related to stock trading in capital markets.

Learning Performance–Level 2, Cluster 1, Sub-Cluster 1

The central theme of these articles is learning performance-related gaming. Articles in this theme focused on using game-based learning to improve student performance in a range of disciplines. There were two types of approaches to performance incorporated in the studies: a measure of actual performance as indicated by student results, and investigations of the impact of gaming on student motivation and commitment to the learning process. The seven articles dealing with direct performance improvements of students using game-based activities in structured courses covered a range of disciplines, including science courses (Sung & Hwang, 2013), health education (Sung et al., 2015), programming knowledge (Wang & Chen, 2010), natural science knowledge for elementary school students (Hwang et al., 2012; Sung & Hwang, 2018), the use of gaming scenarios in defence-related courses (Khamparia & Pandey, 2017), and a course in nutrition for 3rd graders (Yien et al., 2011). The three studies focusing on measuring the impact of gaming on learner motivation included an analysis of the impact of the use of tablet-based games to instill an interest in the mathematical concepts of addition and subtraction (Hung et al., 2015), the application of a game-based approach to developing an understanding of abstract concepts in a course on Confucius thought (Sung et al., 2017), and a study of the impact of collaborative game-based learning using motor sensor technology on the mastery of mathematical concepts (Hung et al., 2017). However, these papers did not adequately differentiate between intrinsic and extrinsic factors that may motivate students to engage in game-based learning activities. In a study of the effects of gamified instructional materials on factors that motivate students to engage with STEM learning, Funa et al. (2021) found that extrinsic motivators can overpower students' intentions to participate in education. They concluded that teacher intervention in gaming activities was critical to ensure that game-related pressures such as time constraints, peer pressure, and overly competitive classmates did not supplant student interest in engaging with gamification from a learning perspective.

Programming and Computing–Level 2, Cluster 1, Sub-Cluster 2

The central theme of these articles concerns programming-related gaming. The majority of papers on this theme focused on gamification to develop programming skills in school students. Among the programming skills-related articles, six papers explored the use of gamification to enhance the interest and competency of elementary school children in learning programming (Demirkiran & Tansu Hocanin, 2021; Förster et al., 2018; Giannakoulas & Xinogalos, 2018; Seralidou & Douligeris, 2021; Shim et al., 2017; Theodoropoulos et al., 2016). An additional six papers explored the role of gamification in developing programming skills in high school students (Holenko Dlab & Hoic-Bozic, 2021; Ouahbi et al., 2015; Pellas, 2016; Pellas & Peroutseas, 2016; Pellas & Vosinakis, 2018a, 2018b). Two articles focused on the use of gamification in developing the programming skills of adults: an analysis of the use of game-based projects using a tool called Scratch to enhance programming skills in engineering students (Topalli & Cagiltay, 2018) and a paper examining the application of a scalable game design to developing programming skills across different ages of learners and disciplines (Basawapatna et al., 2010). The next most significant sub-theme was games to foster computational thinking. Computational thinking is a cognitive ability that facilitates the development of solutions to contemporary problems by applying computer science-related reasoning processes (Wing, 2006). There were nine papers in this genre: (Denner et al., 2012; Hooshyar et al., 2021a, 2021b; Howland & Good, 2015; Kazimoglu, 2020; Kazimoglu et al., 2012a, 2012b; Repenning et al., 2010; Werner et al., 2014). The final paper on this theme explored the comparative impact of gamification, social networking systems, and digital fabrication on student affective learning (Näykki et al., 2019).

English Language–Level 2, Cluster 1, Sub-Cluster 3

The central theme of these studies is English language learning-related gaming. The application of game-based approaches to improve student mastery of English vocabulary was the most dominant focus of articles on this theme, with nine related papers (Chi-Jen et al., 2018; Franciosi, 2017; Huang & Huang, 2015; Hwang & Wang, 2016; Li, 2021; Sandberg et al., 2014; Tsai & Tsai, 2018; Wu et al., 2020; Zou et al., 2021). The use of gamification in developing other English language skills included a paper on the impact on student anxiety of gaming activities designed to develop student competency in English listening (Hwang et al., 2017), an investigation of gamification using mind mapping contextual approaches on improving student writing competency (Fu et al., 2019), and a study on improving student motivation and enthusiasm to learn grammar via a contextual game-based methodology (Lin et al., 2020). A study also explored the overall efficacy of game-based learning across a range of general skill sets (Govender & Arnedo-Moreno, 2021). The use of gamification to develop English language skills in diverse areas such as vocabulary, grammar, and writing raises the question of whether students and teachers favor this form of learning in the same way. A Malaysian study on the use of digital technologies such as games and game chat rooms to develop language skills in English (listening, speaking, writing, vocabulary and reading) explored whether there were differences in the adoption of technology as a language learning aid by students and teachers (Alakrash & Abdul Razak, 2021). The researchers found that there was no significant difference between teachers and students in the usage of digital technologies for the teaching and learning of these five critical skills.

Teacher Adoption of Gaming–Level 2, Cluster 1, Sub-Cluster 4

The central theme of these articles is teacher adoption of gaming. All of the papers on this theme focused on exploring factors relevant to the adoption of game-based approaches to learning by teachers across various learning contexts. Ketelhut and Schifter (2011) looked at the role of professional development in enhancing teacher use of game-based pedagogies for K-12 learners. A professional development model to encourage and facilitate the acceptance of interactive digital gaming in classrooms was proposed in another qualitative study (Stieler-Hunt & Jones, 2019). Bourgonjon et al. (2013) attempted to discover important teacher perceptions and beliefs that trigger acceptance or non-acceptance of gamification in schools as an effective teaching pedagogy. Teacher perceptions were also explored by a study that examined teacher attitudes towards gamification in the context of the technological pedagogical content knowledge-games (TPACK-G) model (Hsu et al., 2020). Lastly, a Taiwan-based study found that the adoption by teachers of game-based teaching was influenced by three factors: lifestyle, perceived attributes of game-based learning, and teacher demographics (Li & Huang, 2016). While the studies in this category provided interesting perspectives on the adoption and integration of gaming applications into school curricula, they did not address the use of data collected by gaming applications that could be used to analyze student success. For example, Kalogiannakis et al.'s (2021) literature review of gamification in science education found that some teachers and researchers used data generated within gaming applications as a non-invasive way to obtain details on student learning processes. Students may be more amenable to formative assessment processes that infuse gaming and data collection into a seamless, less formal process.

Primary and Secondary Education–Level 2, Cluster 1, Sub-Cluster 6

The central theme of these articles relates to primary and secondary school gaming. The articles on this theme all relate to primary and secondary education. Four papers by the same lead author explored the incorporation of video games into the curricula of secondary education courses (Annetta et al., 2009a, 2009b, 2010, 2013). Another four papers (Cheng et al., 2015; Safari Bazargani et al., 2021; Virvou & Katsionis, 2008; Yuana et al., 2015) explored virtual reality gaming in secondary education. Virtual reality is a constructed environment that provides a sense of presence for users in a real or imaginary world (Manis & Choi, 2019). The use of *game* and *non-game* approaches to teaching biology to secondary students was explored in a study involving more than 1,800 high school students and found no discernible difference between the two approaches (Sadler et al., 2015). Another study investigating whether gaming approaches to learning using iPhones or traditional games (without technology) were more effective in teaching children concepts related to multiculturalism and tolerance found no discernible difference in learning outcomes between the two methods (Furió et al., 2013). The final three papers on this theme explored gaming to foster skills development in specific narrow topics. Bioglio et al. (2019) examined the issue of privacy awareness among school children via the use of a social networking game. Another paper looked at enhancing student understanding of heritage issues related to architectural design through virtual reality systems that can emulate building designs (Luigini et al., 2019). The final paper on this theme investigated the use of a multi-touch interactive jigsaw puzzle to improve elementary students' understanding of geographical concepts related to Taiwan (Cheng-Yu et al., 2014).

Mathematics–Level 2, Cluster 1, Sub-Cluster 8

The central theme of these articles relates to mathematics skills development in schools using gaming. This theme contains four studies that were all related to the use of gamification to foster and develop an enhanced understanding of mathematical concepts. The study by Ke (2008) explored whether the incorporation of game-play into math curricula enhanced 4th and 5th graders' achievement in math courses. Two studies examined the impact of game-based learning on the mastery of mathematics concepts by primary school students (Brezovszky et al., 2019; Byun & Joung, 2018). Finally, Byun and Joung's (2018) paper provided a meta-analysis of the trends in digital game-based learning in mathematics curricula for K- 12 students by analyzing 296 empirical studies related to using gaming pedagogies in mathematics courses. The evidence provided by these studies of the beneficial effects of gamification in mathematics suggests a positive trend in the development of game-related mathematics curricula. Traditionally, there have been dissenting opinions on the usefulness of games in supporting mathematics learning, as highlighted by a study investigating the effectiveness of pedagogical tools that incorporate non-electronic games into mathematics teaching (Bragg, 2012). The study concluded that there was no measurable net benefit from using non-electronic games on student mastery of mathematics concepts. It is interesting to note that the apparent increasing effectiveness of the gamification of maths education is occurring during a time of rapid improvements in the sophistication of electronic gaming systems, which are accompanied by changing pedagogical practices.

CONCLUSION

Gamification is an important tool in an educator's arsenal of strategies to deliver effective education. This study employed *CitNetExplorer*, a bibliometric tool, to establish the current status of the use and integration of gamification in different educational contexts. The results revealed 10 important themes characterizing the use of gamification in education: mobile gaming, physical education, health and medicine, business, learning performance, programming and computing, English language, teacher adoption, primary & secondary education, and mathematics. Further, this study found increasing interest in integrating bespoke gaming applications for specific knowledge domains. Examples of these from studies examined in this review include ASTRA EAGLE, a suite of mathematics learning games, a mind-mapping contextual game designed to provide students of English in a tourism program with a virtual experience of popular tourist spots in China, and a software program called *Communica-Enf*, which was designed to develop nurse-patient communication skills using a virtual patient. The continued effort to develop customized gaming applications that target specific skills development is likely to continue, as learner demands for novel and interesting alternatives to traditional teaching pedagogies evolve.

The results of this study into the usage of gamification in different academic disciplines have significant ramifications for a range of stakeholders. First, designers of serious games may benefit from understanding the knowledge domains that dominate the constructive use of gaming applications. Educators of all disciplines across the three tiers of education (primary, secondary, and tertiary) need confidence that serious games that claim to support knowledge acquisition in specific disciplines are actually constructed with that goal in mind. Game design frameworks that incorporate subject-specific learning outcomes are more likely to be accepted as valued learning tools. Second, institutions reluctant to invest in gaming technologies may gain confidence in the knowledge that research into the integration of serious games into course curricula reveals substantial benefits to student knowledge acquisition, such as improved learning outcomes and increased motivation to learn. Last, educators themselves may benefit from the experiences of other researchers who have leveraged features inherent in serious games that enhance knowledge acquisition while also minimizing aspects of game-play that are not aligned with the goals of established curricula.

This analysis of the state of play of gamification in education is not without its limitations. The choice of *CitNetExplorer* to conduct the bibliometric analysis, a software environment integrated with WOS, constrains access to other article databases and citation-relation methodologies. Further, the reliance on English-only publications precludes articles from countries such as Japan, Korea and China that are published in their native language. Future survey-based studies into gamification that attempt to contrast student and teacher experiences across disciplines, education sectors, and countries would make a useful contribution to the contemporary understanding of this phenomenon. Future research could also explore gaming devices, applications, and gamification frameworks that affect pedagogical practices and outcomes in diverse educational settings. The authors hope that this paper has provided some insight into the educational domains where gamification has been applied.

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