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Exploring the Research Trajectory of Digital Game-based Learning: A Citation Network Analysis

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ABSTRACT: The digital revolution has heavily influenced digital game-based learning, yet as the revolution progresses, the conception of such learning has shifted along with the increasing complexity of the digital environment. Our study thus aims to identify research standing at this important juncture and to explain the shift in digital game-based learning research fields by adopting an integrated approach of main path analysis that yields this topic's knowledge diffusion. Using key-route 8 to construct the path, we collect a total of 2156 articles and their data from The Web of Science database. From over 30 years of digital game-based learning development, 26 of the most influential studies are identified and visualized using Pajek software. The findings show two development phases for this field: exploring the role of gaming for educational purpose as well as facilitating learning performance. The research focus in the first phase prominently explores the potentials of digital games for educational purposes, and then the focus evolves in the second phase into actualizing the identified potentials. We propose a framework of digital game-based learning affordance actualization to explain these shifting phenomena in the specific research fields. Furthermore, unveiling the changing conception of digital game-based learning research is important for instructional designers, scholars, and educators to truly understand how technology can enhance teaching and facilitate learning performance.

Keywords: Affordance actualization, Main path analysis, Digital game-based learning, Citation network, Knowledge diffusion

1. Introduction

Research on game-based learning has attracted widespread scholarly attention over the last few decades. Due to the rapid growth and public acceptance of technologies, academic studies related to digital game-based learning (DGBL) have grown very fast since 2006 (Hwang & Wu, 2012). Although the digital revolution has heavily influenced DGBL, its concept is not only growing alongside with the development of digital technologies, but also changing the education paradigm. The integration of modern technology and gaming in the learning and educational context is not a new concept, yet the broad spread of digital game acceptance has attracted instructional designers, researchers, and educators to further explore its potential (Plass et al., 2015). DGBL started out by focusing on the usage of digital technology to increase students' learning achievement, but over the years it shifted its major attention to the alignment between technology and learning environment to satisfy numerous learning needs. Over the last three decades, influenced by technology advancement and entertainment gaming trends, the concept of DGBL has been constantly changing.

Over this course of time, an abundant amount of studies has proven the effectiveness of educational computer games to support learning programs as a way for increasing student motivation and engagement in various subject areas, such as natural science courses (Hwang et al., 2013; Sung & Hwang, 2013), English as a foreign language (Huang & Huang, 2015; Lin et al., 2020), mathematics (Ke, 2008; Ku et al., 2014), computer science and engineering (Coller & Scott, 2009; Ebner & Holzinger, 2007), health (Quail & Boyle, 2019), and geography (Tüzün et al., 2009). Moreover, with the number of publications on this subject growing, several review studies have been conducted to identify the current development and research trends of the DGBL field over a certain period (Hwang & Wu, 2012; Tsai & Fan, 2013). Cheng et al. (2020) show the importance of reviewing based on highly cited articles, arguing that such articles represent highly valued topics and important trends due to having solid pedagogical theories and well-recognized data analysis methods.

Liu and Lu (2012) conversely point out methods that identify the most significant path in a large citation network, which is main path analysis. In contrast to citation counts, main path analysis not only considers the direct influences, but also takes indirect influences into account. Assuming that citation links represent diffusion

of knowledge from one work to another, this method assigns values to the link that connects two documents instead of directly assigning values to the documents themselves. Therefore, this method identifies significant "links" in lieu of important "nodes." The nodes associated with the link are still considered important. Thus, the results obtained from citation counts might be different from the results obtained from the main path method. This method is also effective in highlighting a sequence of major historical development events in a complex citation network. Therefore, main path analysis is a powerful strategy for tracing the evolution of a science or technology throughout history (Liu et al., 2019; Liu & Lu, 2012).

Regardless of the valuable insights that have been provided from previous review studies, large and complex citation networks have continuously emerged as a side effect of the rapidly increasing interest in this topic every year. To the best of our knowledge, no papers have employed a study of significant historical development events in a complex citation network of DGBL. Analyzing the citation network of DGBL can help us identify the critical intellectual development milestones of DGBL studies and identify their development trajectory. Understanding the exponential growth of the DGBL literature can also reveal the dynamic nature of this field. Given this importance, surprisingly little if any research has been conducted on the origin and how DGBL studies evolve over time.

The trajectory of knowledge, resulting from main path visualization, can tell us something about the changing nature of the digital technology and learning nexus that needs to be explained. Furthermore, actualizing the potential of a digital game in education, represented by affordance, may contribute to the success of DGBL and improve the learning experience. All in all, conducting main path analysis to find the most important works in the DGBL research fields and explaining how these fields have evolved are imperative and beneficial.

The purpose of this study is to identify works standing at an important juncture and to explain the shift in DGBL research fields through main path analysis. This study utilizes the Web of Science Database covering the Science Citation Index Expanded (SCI-EXPANDED) and Social Sciences Citation Index (SSCI) about the subject of DGBL. The research questions are listed as follows.

RQ1. Which research studies have the most influence on the development of the digital game-based learning literature?
RQ2. How has the research of digital game-based learning evolved?

To answer these research questions, this study adopts main path analysis and utilizes systematic literature research to trace 30 years of DGBL's development trajectory. Furthermore, Strong et al. (2014) affordance actualization lens is applied as a theoretical method to further understand the shifting phenomena in the DGBL research field (Hwang et al., 2021).

This study fills the gap in the literature and contributes to DGBL research by proposing several distinctions. First, in contrast to previous review papers focusing on a certain aspect of DGBL or based on highly cited articles, this study targets all research that has been published in the 30 years of DGBL. Second, we identify the most significant works based on the citation network of DGBL research fields. Third, knowing the most important juncture in the historical development of DGBL research fields will tell us something about the changing nature in their evolution. Thus, in this study we shall explain the evolution of DGBL research fields.

2. Research methodology

2.1. Data collection

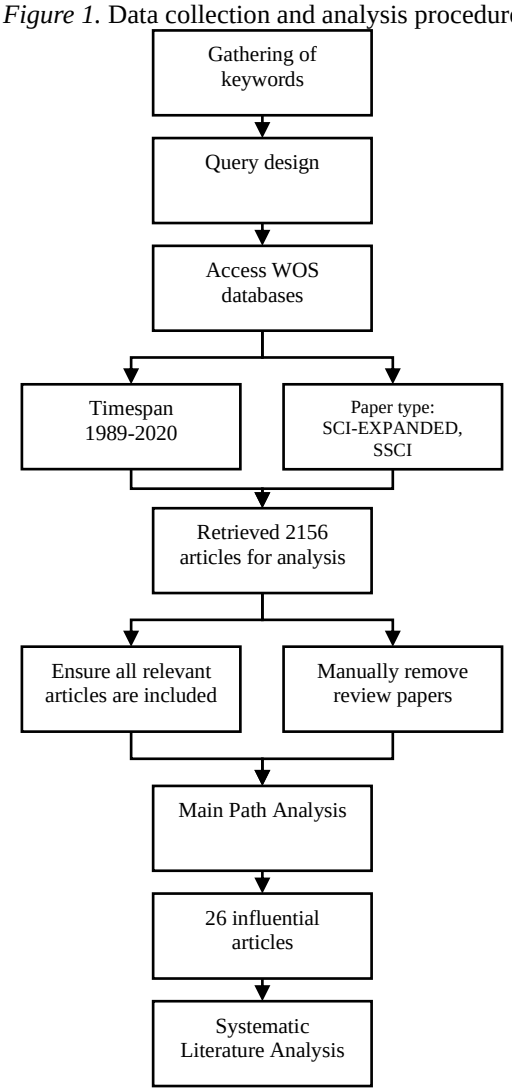
Figure 1 below explains the procedure of data collection and evaluation. Our goal is to have a complete dataset, which includes as many relevant articles as possible and excludes those that are irrelevant. To achieve its goal, this study follows four steps of data collection by Chuang et al. (2017).

First, we list several related keywords by reviewing five recent review articles in the field of DGBL (Acquah & Katz, 2020; Hung et al., 2020; Lai & Bower, 2020; Martin et al., 2020; Noroozi et al., 2020). Second, the keywords gathered help further design our search strategy to narrow the search results. Based on the searching strategy, the following query is used to narrow the search result:

TS=((game-based AND learn) OR (gamif* AND learn*) OR "education* computer game*" OR "serious computer game*" OR "digital serious game*") NOT TI=review*

The Web of Science core collection is used to search and collect published articles that are going to be used for our study. Our datasets cover the Science Citation Index Expanded (SCI-EXPANDED) and Social Sciences Citation Index (SSCI) from 1991 until the day of data collection, which is May 18, 2021. In the third step, we aim to ensure all relevant articles are included in our dataset by reviewing reference sections of selected review papers mentioned previously and manually adding any missing papers into our dataset. Furthermore, we make sure that all the highly cited DGBL papers in the WOS Database are included in our dataset. To get an objective result, we purposely exclude review papers, because in general they are highly cited not because of their original ground-breaking results, but rather due to their comprehensive summary of the results of a field (Ho et al., 2017; Liu & Lu, 2012). Thus, in the last steps we manually remove review papers in the datasets. The search query results in 2156 research articles. We then export all the record content and citation information of the search results and proceed with constructing main path analysis.

Figure 1. Data collection and analysis procedure



2.2. Main path analysis

The total number of all publications in a scientific field is relatively large, and therefore a quantitative approach is needed to make it possible to analyze the large data in a citation network. Main path analysis is a citation-based method that extracts the backbone of a large citation network. It was first introduced by Hummon and Dereian (1989), assuming that knowledge from previous research disperses to later research through citations. Main path analysis calculates the extent to which a particular citation or article is needed for linking articles (Nooy et al., 2018). In that sense, citations that are needed in paths connecting many articles carry more significance than those that are barely linked to any articles (Calero-Medina & Noyons, 2008; Nooy et al., 2018). As the citation network in a scientific field is growing rapidly, the citation network is becoming massive and more complex. Batagelj (2003) advance Hummon and Dereian's (1989) weights by proposing efficient

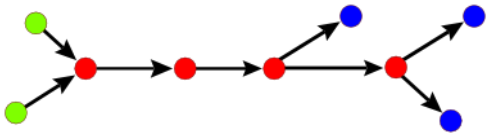
algorithms for determining various versions of the significance index, so that they can be used for analysis of a very large citation network. They implemented the algorithm in Pajek software for analysis of large networks, and thus their advancements accelerated the use of path analysis (Batagelj, 2003; Lathabai et al., 2018; Liu & Lu, 2012)

The original main path approach does have some limitations (Liu & Lu, 2012). In the original main path method, the search procedure is to find the single most significant path for the whole network. As Liu and Lu (2012) note, the path resulting from this approach cannot guarantee that this single path is the most significant among all paths in the whole network, and it does not allow to find the significant nodes that bring together ideas from many earlier publications. To overcome this limitation, they set up an approach that integrates several methods into one analysis, which are the global method, backward method, multiple main path method, and key-route search method.

This breakthrough, particularly the key-route method, is an excellent tool for visually displaying the development structure of an entire scientific field, which suggests a divergence-convergence-divergence process on that structure (Liu et al., 2019; Liu & Lu, 2012). The key-route approach ensures that significant top links in the citation network are included in the main paths, thus complimenting the aftermentioned limitations. The path constructed from the key-route method is based on the most significant links with the highest traversal counts as a seed link, and then it searches forward and backward until a “source” and a “sink” are hit. The path is then constructed by connecting all the resulting networks. Although the key-route approach has the possibility to determine as many seed links as possible, the higher the seed link number is that ones decide, the more complex the network will be.

Main path analysis operates in two steps. It first determines the traversal count of each citation link from each source to each sink. It then searches for the main path by linking citation links based on size of traversal counts. A number of terms must be defined to precede with the discussion of traversal weights. As shown in Figure 2, there are 3 types of nodes in a citation network: source, intermediate, and sink. Source nodes are articles that are cited by others, but are not citing within the datasets. Intermediate nodes are articles that are citing and cited by others. Sink nodes are articles that are citing others, but not cited within the datasets. Apart from nodes, in the citation network there are arrows as well. The arrows denote their links; the thickness of the line indicates the traversal counts of the links. Thus, the thicker the line is, the more significant is the link (Liu & Lu, 2012).

Figure 2. A simple citation network



The three basic methods to determine the traversal weight are SPC (search path count), SPLC (search path link count), and SPNP (search path node pair). The method in calculating search path count is determined by how to define source and sink. In the SPC method, traversal weight is calculated from the number of links traversed by all possible paths from all sources (green nodes) to all sinks (blue nodes). In the SPLC method, all nodes before a particular link are also seen as a source, including intermediate nodes (red nodes). In SPNP, all nodes before a particular link are seen as a source, and all nodes after a particular link are seen as a sink.

A key differentiation between SPC and SPNP is that SPC sees the intermediate node as merely an intermediary for knowledge to flow, but SPNP considers it a knowledge depository as well, whereas knowledge diffusion in the scientific and technological world does not work this way. Thus, the most appropriate method for calculating the search path is SPLC. This is because SPLC treats intermediate nodes that are not only seen as passing the knowledge, but also are knowledge sources as well. Therefore, for tracing the knowledge diffusion trajectory in scientific and technological development, Liu et al. (2019) note that SPLC is the most recommended search path count method.

3. Findings and analysis

The trend of DGBL research is still growing. After performing main path analysis from 1991 to May 18, 2021, the total number of works published adds up to 2,156. We apply Loglet Analysis to the publication data to see the growth trend of publications studying this topic. Loglet Analysis is a logistical trend analysis tool designed to

analyze sets of time-series data and decompose the growth process into S-shape logistic components (Meyer et al., 1999).

Figure 3 below shows the growing trend of DGBL research over the years. As seen in the figure, its growing trend has continued to increase with attention and interest over time. Our findings are in line with previous studies demonstrating that DGBL studies have become more and more important over the past decade, as many researchers recognize the potential benefits of computer games for learning (Chen et al., 2020; Hwang & Wu, 2012). Based on the analysis, if this trend persists, then we predict that the growth of this research topic will continue to expand until 2030.

Figure 3. DGBL research growth trend (historical and projected)

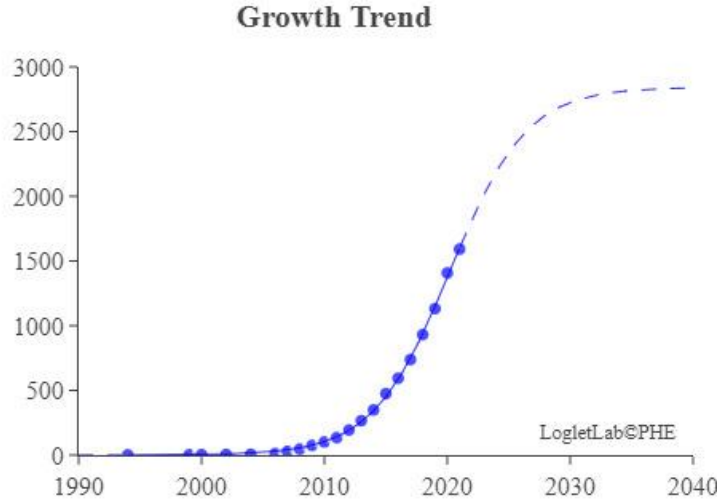
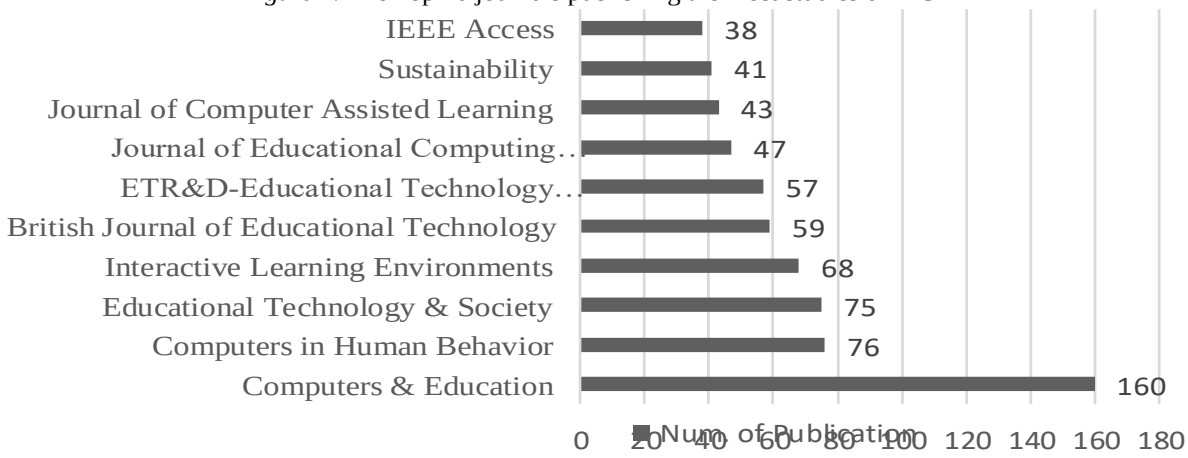


Figure 4 shows the main journals that publish the most studies on DGBL. We count the number of publications in the DGBL field and show only the top 10 list of journals. Computers & Education has the greatest number of publications due to its scope, which focuses on pedagogical uses of digital technology, while Computer in Human Behavior focuses on wider topics that cover the use of computers from a psychological perspective, including the psychological effects of computers on learning. Educational Technology & Society is in the third position in terms of its publication number of DGBL research. Although ET&S and Computer in Human Behavior focus more on research in educational technology, their number of publications does not exhibit much of a difference.

Figure 4. The Top 10 journals publishing the most studies on DGBL



3.1. Cross-citation network of the DGBL literature

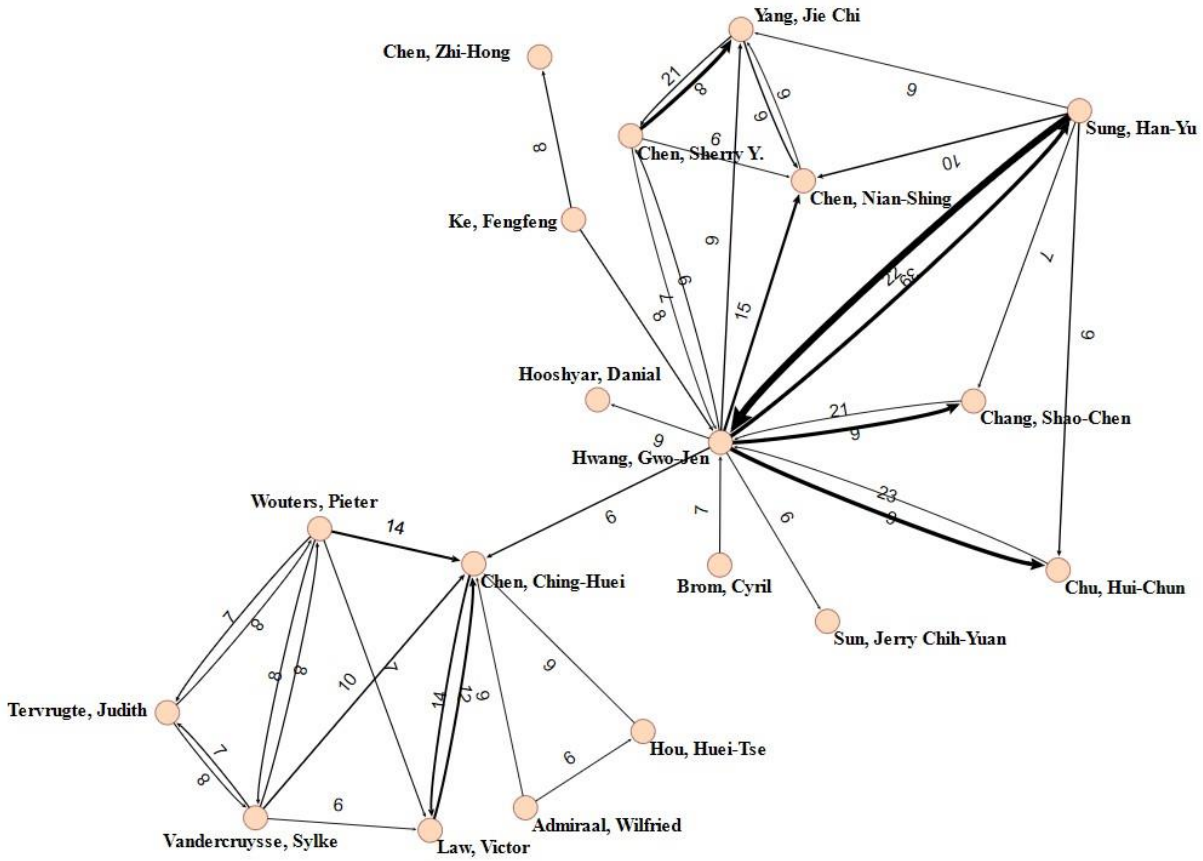
The cross-citation network shows how knowledge is created and distributed among authors. Analyzing the cross-citation network is one way to observe authors' correlation with each other. In the knowledge creation process,

an author gets knowledge from other authors, and so the knowledge possessed by an author is dispersed to other authors. The cross-citation network shows the main network of references cited by the authors in the DGBL field. This network can give us useful insight on the distribution of the co-author citation network and the knowledge creation process (Za & Spagnoletti, 2013).

Figure 5 shows a co-author cross-citation network in the DGBL literature. We identify a total of 4,367 authors from 2,156 research articles. The resulting network are highly complex since there are so many nodes and links. In order to gain more insight into this network, it may be more beneficial to analyze its social cohesion. The cohesion in a network means that the cross-citation network contains many links. Thus, more ties between authors result in a tighter and more cohesive structure.

We set some boundaries to simplify the networks and show only the most cohesive ties between the authors in the DGBL research field. First, we set first author as the key author and remove authors who published less than 5 articles. Second, we remove the lines with a value lower than 6 and then reduce all degrees (in-degree and out-degree) of the network by 16. The degree of a node is the number of links each node is involved. Thus, the more link a node is connected to, the more cohesive the network will be. There are two types of degree: in-degree and out-degree. In-degree means the number of links it receives, whereas out-degree means the number of links it sends. In the cross-citation network, the nodes represent the first author, and the arrows indicate the citation relationship. For example, from *Wouters, Pieter* to *Chen, Ching-Huei* means *Wouters, Pieter* cites *Chen, Ching-Huei* articles 14 times. The arrow width shows how strong the ties are between authors. Thus, as we can see from the network the strongest ties are between *Hwang, Gwo-Jen* to *Sung, Han-Yu*. This network also shows that there are two clusters of knowledge distribution among authors. Between the two clusters, we can see that the links between *Hwang, Gwo-Jen* and *Chen, Ching-Huei* are the bridges of knowledge diffusion. Thus, *Hwang, Gwo-Jen* and *Chen, Ching-Huei* are the articulation point on this cross-citation network. Their connection plays an important part in the flow of knowledge in their fields and may contribute to the innovation creation process.

Figure 5. Co-author cross-citation network



3.2. Main path analysis of digital game-based learning

We perform main path analysis to uncover the more critical development path in DGBL research. The main path is represented by using key-route 8, which means the path is constructed based on the top 8 links with the highest traversal counts, and then it searches forward and backward until a "source" and a "sink" are hit. We believe that key-route 8 adequately represents prominent junctures in DGBL research fields. Our observations indicate that numerous significant links are represented, while paths of lesser significance are ignored, thus offering a bird's eye view of the complex citation network of DGBL.

Table 1 below is the list of the highest traversal links used as a seed link in constructing the network in this analysis. The highest traversal links are believed to be the most significant path, because they bring together ideas from many earlier publications. Thus, the most influential articles that contribute to the development of the DGBL research field can be viewed as the main path constructed from the most significant publications.

Table 1. The highest traversal links

Counts	Traversal Counts (SPLC)	Routes
1	179240.00	HwangSHYH2013 => HwangSHHT2012
2	177632.00	HungSY2015 => HamariSRCAE2016
3	154656.00	SungH2013 => HwangYW2013
4	138804.00	HwangWC2012 => SungH2013
5	132348.00	HwangSHHT2012 => SungH2013
6	86112.00	SungH2013 => HungSY2015
7	85284.00	HwangYW2013 => HwangCC2015
8	84666.00	HwangYW2013 => HwangHC2014

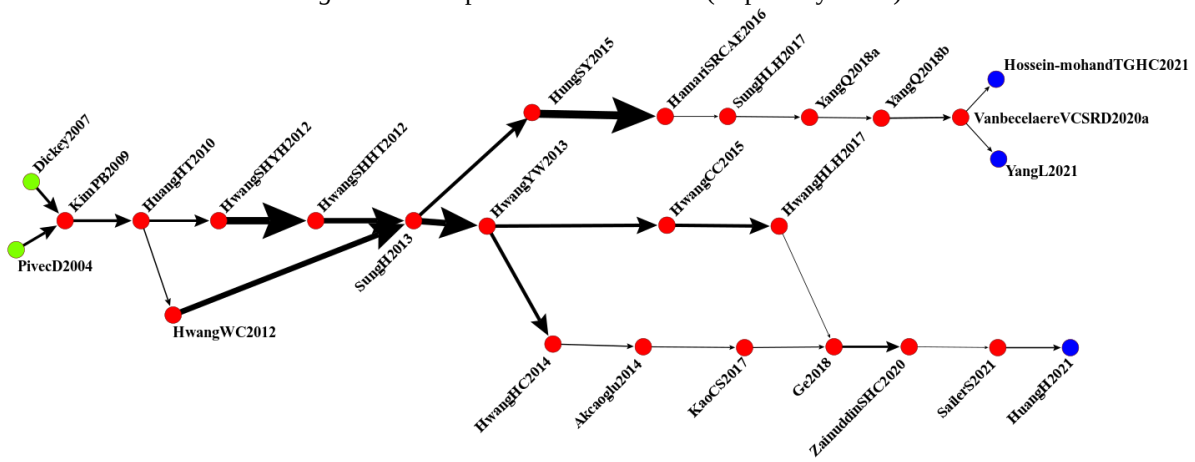
Table 2. Papers by region focus

Label	Author(s)	Region Focus
PivecD2004	Pivec & Dziabenko (2004)	Austria
Dickey2007	Dickey (2007)	United States
KimPB2009	Kim et al. (2009)	South Korea
HuangHT2010	Huang et al. (2010)	United States
HwangWC2012	Hwang et al. (2012c)	Taiwan
HwangSHHT2012	Hwang et al. (2012a)	Taiwan
SungH2013	Sung & Hwang (2013)	Taiwan
HwangYW2013	Hwang et al. (2013)	Taiwan
HwangSHYH2012	Hwang et al. (2012b)	Taiwan
HwangHC2014	Hwang et al. (2014)	Taiwan
Akcaoglu2014	Akcaoglu (2014)	Turkey
HwangCC2015	Hwang et al. (2015)	Taiwan
HungSY2015	Hung et al. (2015)	Taiwan
HamariSRCAE2016	Hamari et al. (2016)	United States
HwangHLH2017	Hwang et al. (2017)	Taiwan
SungHLH2017	Sung et al. (2017b)	Taiwan
KaoCS2017	Kao et al. (2017)	Taiwan
YangQ2018a	Yang & Quadir (2018)	Taiwan
YangLC2018	Yang et al. (2018)	Taiwan
Ge2018	Ge (2018)	China
YangQ2018b	Yang & Quadir (2018)	Taiwan
ZainuddinSHC2020	Zainuddin et al. (2020)	Indonesia
VanbecelaereVCSRD2020b	Vanbecelaere et al. (2020)	Belgium
SailerS2020	Sailer & Sailer (2020)	Germany
HuangH2021	Huang & Hew (2021)	Hong Kong
Hossein-mohandTGHC2021	Hossein-Mohand et al. (2021)	Spain

Figure 6 shows the critical development path of DGBL studies. The finding reveals that there are 26 most influential articles published from 2004 to 2021. The data are then visualized using the Pajek software. The nodes are represented by a different color. Green nodes are the source nodes, red nodes are intermediate nodes, and blue nodes are sink nodes. The arrows denote the direction of knowledge flow, and the thickness of the line indicates the traversal counts of the links. The thicker the line is, the more significant is the link (Liu & Lu, 2012).

Each paper is assigned with a code. This code consists of the last name of the first author, followed by the latter authors' initials, and ends with the publication year. As an example, the study from Pivec and Dziabenko in 2004 is coded as PivecD2004. In case there are duplicate codes, then the codes have lower-case letters added at the end, such as YangQ2018a and YangQ2018b, which are written by Jie Chi Yang and Benazir Quadir in the same year.

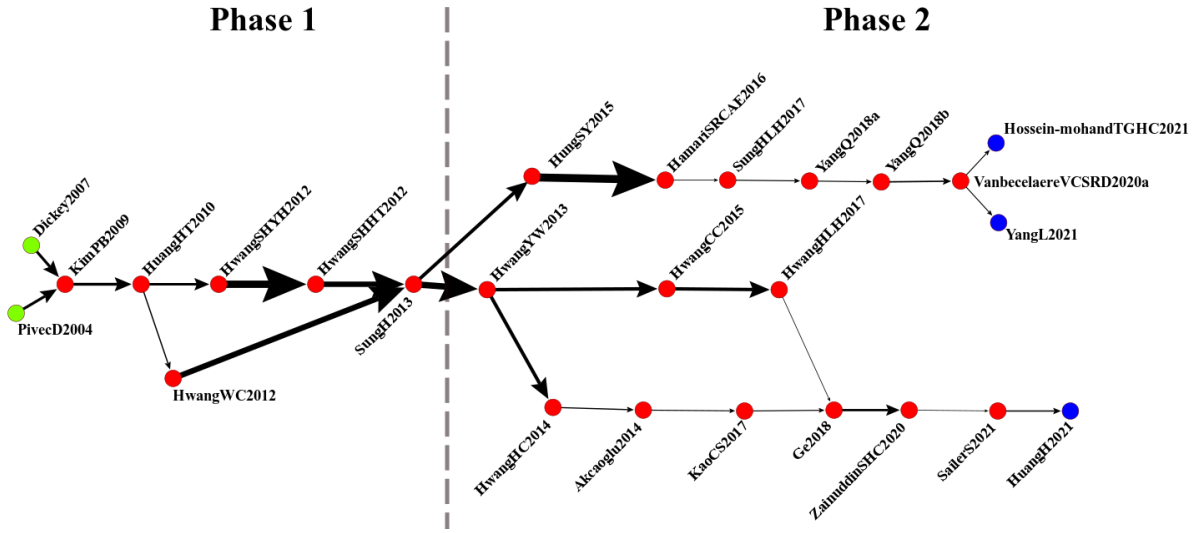
Figure 6. Main path of DGBL studies (Top 8 Key-route)



Based on main path analysis, we find that the most influential articles in the DGBL research field have been carried out in Taiwan, followed by United States (see Table 2). The author who has appeared the most out of the 26 most influential articles is Gwo-Jen Hwang, appearing in 9 out of 26 most influential articles, followed by Jie Chi Yang appearing in 3 articles.

We next study the articles to better understand the main path results. From studying those articles on the main path, we divide the DGBL research development into two major stages (Figure 7). The early days of DGBL research appear to focus on the development of an interactive learning environment and demonstrate how various aspects of computer games have great potential to improve the learning process. In the second phase, the trends of DGBL research bifurcate into three areas.

Figure 7. Development trajectory of digital game-based learning studies



3.2.1. Exploring the role of gaming for educational purposes

Games have evolved from traditional games to handheld electronic games, and along with the rise of the Internet in the 1990s, online gaming started to thrive. Online gaming allows players to link up together, thus enabling them to collaborate and/or compete to win a game. Its popularity has attracted the attention of researchers and educators to explore its potential in providing a new innovative way of learning (Plass et al., 2015). Driven by

the desire to enhance the learning environment by presenting this new and innovative technology to build digital games for educational purposes, DGBL has thus become an emerging research topic.

Two critical sources that shape today's DGBL research are the studies of Maja Pivec and Olga Dziabenko in 2004 and Michele D. Dickey in 2007. Pivec and Dziabenko (2004) propose a new way of learning by introducing a collaborative learning-social skill game concept based on the constructivist learning approach and collaborative learning, UniGame. Their study contributes to how collaborative learning can be applied in a fun and engaging way with the use of (digital single-player) online-role playing games.

Along with the trends of casual games, DGBL research trends also shifted. In the 2000s, a ground-breaking game genre emerged. One of the most popular game genres is the Massively Multiple Online Role-Playing Game (MMORPG), which allows thousands of players to interact at the same time in an online gameplay environment. The popularity of the MMORPG game genre soon attracted instructional designers, researchers, and educators to further explore its potential. Examining how some elements in MMORPG's game design can support intrinsic motivation, Dickey (2007) suggests that its design may provide a practical model for creating interactive learning environments by providing choice, control, collaboration, challenge, and achievement. Her findings give insightful contributions to instructional designers and educators to develop an interactive and engaging learning environment.

Keeping in line with the source knowledge, researchers in the following years continued to explore the role of digital game for educational purposes by developing educational computer game design, features, and game concepts (Tsai & Fan, 2013). Hwang et al. (2012c) redefine the research in the field by developing a competitive board game with an online game approach. Later in the same year, Hwang et al. (2012b) state that without proper learning strategies or supportive models, the learning achievement of students might not be as good as expected. Thus, they propose a knowledge engineering approach for developing educational computer games, the Repertory Grid Method. This approach shows significant improvement for students' learning performance in differentiating knowledge. They also realize that some issues need to be further investigated.

In their next research, Hwang et al. (2012a) investigate the effect of students' learning styles on their performance. They present a personalized educational computer game and examine its effectiveness in improving the learning achievement of students. They argue that students' learning styles are an important human factor, and so they believe in the development of educational computer games that individual students' learning needs or difficulties must be considered.

Research predominantly in this phase are the most crucial ones that intend to explore what potential advantage a digital game offers and what roles do digital games have in education. Researchers in this stage are predominantly trying to find answers to the questions, "Can any specific game features be shown to be more effective at supporting learning?"; "Can any game concepts be adapted to suit varying types of subjects and learning styles?"; and "How can an educational computer game be designed effectively to aid student learning?" From a design science perspective, this process can be seen as a design cycle, where digital games as an IT-artefact are constructed, rigorously and thoroughly tested in an experimental situation, and refined further until a satisfactory design is achieved (Hevner, 2007). These aforementioned studies play an important role in providing the foundation of DGBL.

3.2.2. Facilitating learning performance

In the second stage of the development trajectory of DGBL studies, researchers began to bifurcate into three big areas with the main purpose of facilitating learning performance. The first stream focuses on how to make students become engaged, motivated, and have a better experience in an interactive learning environment. The second stream targets how the educational computer game can help students to improve their performance and achievement through different learning strategies. The last stream looks into how DGBL or game concepts can be applied in the classroom to improve classroom teaching.

The researchers in the first stream acknowledge that to be able to gain the greatest potential of DGBL, students need to be engaged, motivated, immersed, and have a better experience in an interactive learning environment (Hamari et al., 2016; Hung et al., 2015; Sung et al., 2017). Thus, much of the research in this area discusses the best approach to enhance students' learning experience in terms of their engagement, learning motivation, and/or immersion. Hamari et al. (2016) and Hung et al. (2015) both argue that challenging games can improve students' learning achievement. Hamari et al. (2016) state that challenging games should be able to keep up with students' growing abilities as a means to keep them maximally engaged in continuous and constant learning. Sung et al.

(2017) report that to increase students' motivations and engagement, experiential learning needs to be integrated into the gaming elements, given that if this aspect is removed from the learning process, then students might not be able to be motivated, to understand the game, or even to interact.

Several studies propose a different game design by integrating learning strategies into gaming scenarios to improve students' performance and learning achievement. Hwang et al. (2013) develop an educational role-playing game and embed the concept maps approach in gaming scenarios and missions. They argue that concept mapping is effective at improving students' learning achievement, especially in natural science courses. Hwang et al. (2015) also focus on improving students' performance and learning achievements. They develop a contextual educational computer game to investigate the effectiveness of an inquiry-based learning strategy on students' learning achievement, learning motivation, degree of satisfaction, and their flow state in a social studies course.

The third stream of research mostly discusses how to incorporate DGBL into in-class activities as instructional tools. For example, Kao et al. (2017) suggest that individual instructors could customize a digital game to achieve their personal instructional goals by administering self-designed learning scaffolds into the game. Zainuddin et al. (2020) investigate the role of e-quizzes on students' learning and engagement. They report that incorporating a game or game concepts into the classroom can be beneficial for educators to retain students' attention and increase their engagement. This view is echoed by Sailer and Sailer (2020), who state that gamified e-quizzes can foster engagement and fun in the classrooms.

4. Discussion

Through main path analysis, we identify two main stages of the DGBL research evolution. The first stage is an exploration of the role of gaming for educational purposes. The early stages are the most crucial ones that intend to explore what potential advantage a digital game offers and what roles do digital game have in education. "Can any specific game features be shown to be more effective at supporting learning?"; "Can any game concepts be adapted to suit varying types of subjects and learning styles?"; and "How can an educational computer game be designed effectively to aid student learning?" are the main questions that the researchers in this stage are trying to answer.

These studies pay great attention to the perceived and actual properties of digital games, which we term "affordance." Strong et al. (2014) define affordances in an organization as *the potential for behaviors* [to be] *associated with achieving an immediate concrete outcome and arising from the relation between an artifact and a goal-oriented actor or actors.* In this sense, the affordances are the product that arises from the relation of "actors and their goals" (students and/or teacher) and "IT-artefact" (digital game). Acknowledging the affordances that arise from introducing the digital game into education is just the beginning of understanding how this relation implicates the change in an educational organization. Thus, affordances need to be actualized by a goal-oriented actor to achieve an outcome (Strong et al., 2014). Furthermore, Strong et al. (2014) define actualization as *the action taken by actors as they take advantage of one or more perceived affordances through their use of technology to achieve outcomes in support of organizational goals*.

After reviewing the trajectory of knowledge of the DGBL field, we find as a result of the interaction between a goal-oriented actor and digital game in the first phase that researchers then took action to actualize digital game-based learning and achieve an outcome. This outcome is what we find in the second stage of DGBL evolution: facilitate learning performance.

Figure 8 explains that the research focus in the DGBL field is evolving. The arrow indicates the knowledge flow from one work to another work, whereas the thickness of the line denotes its traversal counts.

Over the past decade, Information System researchers have been exploring the affordance actualization lens to understand how information technology is implicated in organizational change processes (Volkoff & Strong, 2017). We believe the change of research topics in the development trajectory of DGBL can be explained better by the theory of affordance actualization. After conducting an extensive literature review, we believe that the affordance actualization used in the field of organization change (Strong et al., 2014) can also be applied to explain the change in DGBL research field. Therefore, we propose a model of Digital Game-based Learning Affordance Actualization (Figure 9).

Figure 8. The transformation of research focus: Actualizing the affordance of digital game-based learning

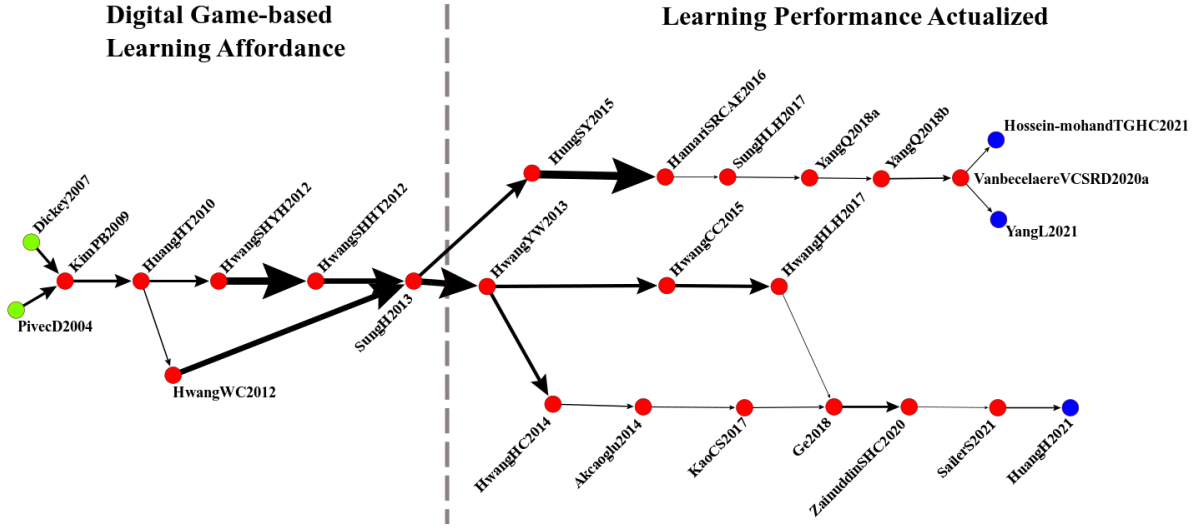
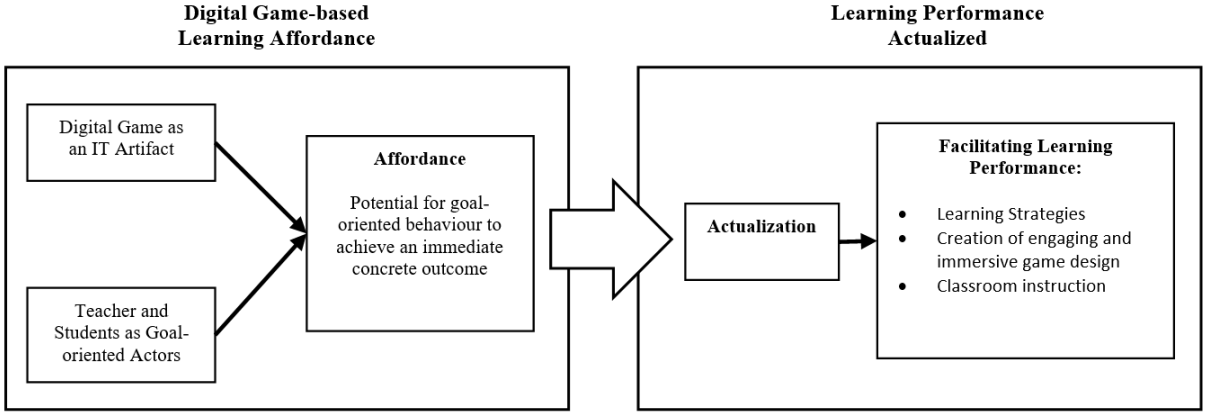


Figure 9. The digital game-based learning affordance actualization model



As we mention above, the first phase of DGBL development trajectories is driven by the desire to enhance the learning environment by presenting new and innovative technology to build digital games for educational purposes. The researchers focus on exploring the potential of digital games and continuously develop them for educational purposes. The second phase of DGBL development trajectories is driven by the effort to actualize DGBL potentials. The researchers look at learning performance through 3 aspects: learning strategies, the creation of engaging and immersive game design, and classroom instruction.

5. Conclusion

The strength and essence of the MPA Approach are that it is able to highlight a series of major developmental events in the field of DGBL research, due to its ability to trace the progress of important works over time. This present study conducts main path analysis to trace the development trajectory of DGBL over a 30-year period. We identify a total of 26 out of 2156 papers related to DGBL as the most significant works.

After analyzing the most significant research that has shaped the development trajectory of DGBL, we present two stages of the evolution of DGBL research focus. In the first stage, most studies focus on developing a game design, feature development, and game concept, while continuously exploring the potential of gaming for educational purposes. Our analysis finds that the evolution of this research focus results from the interaction between a “teacher and students with its goal” and “digital game” in the first phase. Studies then took action to actualize digital game-based learning to achieve an outcome that we note in the second phase of the DGBL evolution. This finding highlights the changing concept of DGBL, which is becoming increasingly complex compared to its early emergence. Thus, understanding the changing concept of DGBL is crucial.

Based on our findings, we propose a model of digital game-based learning affordance actualization. Our proposed model consists of two phases: affordance and actualization. Affordance arises from the relationship between teacher and students as goal-oriented actors and the digital game as an IT artifact. Actualization is the realization of those potentials.

This study contributes to the DGBL literature by offering several distinctions. First, we analyze all the research that has been published related to DGBL since the first time this topic emerged. This fills the gap of previous review paper-related research that only focused on certain aspects of DGBL or were based on a certain period of time. Second, by adopting main path approach, we are able to identify the most significant works in a large and complex citation network of the DGBL literature. Third, knowing the most important juncture in the historical development of DGBL research fields can tell us something about their changing nature in the growth of scientific knowledge. Thus, in this study we explain the evolution of the DGBL literature. An improved understanding of the shift in its evolution may improve the design of learning activities using a game as a better way of learning.

In conclusion, this paper extends prior research by identifying works standing at an important juncture and explains the shift in the DGBL literature through main path analysis. This article presents an extensive literature review with main path lens, which may help new researchers who are considering to enter DGBL research gain insight into what has already been achieved and what should be pursued in future investigations. Understanding the digital game-based learning affordance actualization model will assist instructional designers and educators at developing and creating interactive learning environments by applying a proper learning strategy, creating an engaging and motivating learning environment, and how to construct DGBL into the classroom setting, thus enhancing teaching to facilitate stronger learning performance.

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Appendix

Table A1. Most influential studies in DGBL literature

Label	Author(s)	Title	Subject Area	Participants
PivecD2004	Pivec & Dziabenko (2004)	Game-based learning in universities and lifelong learning: "UniGame: Social Skills and Knowledge Training" game concept	Not specified	Not specified
Dickey2007	Dickey (2007)	Game design and learning: a conjectural analysis of how massively multiple online role-playing games (MMORPGs) foster intrinsic motivation	Not specified	Not specified
KimPB2009	Kim et al. (2009)	Not just fun, but serious strategies: Using meta-cognitive strategies in game-based learning	Not specified	Ninth-grade students
HuangHT2010	Huang et al. (2010)	Sustaining iterative game playing processes in DGBL: The relationship between motivational processing and outcome processing	Economics	Undergraduate students
HwangWC2012	Hwang et al. (2012c)	An online game approach for improving students' learning performance in web-based problem-solving activities	Natural science course	Fifth and sixth graders of an elementary school
HwangSHHT2012	Hwang et al. (2012a)	Development of a personalized educational computer game based on students' learning styles	Natural science course	Fifth graders of an elementary school
SungH2013	Sung & Hwang (2013)	A collaborative game-based learning approach to improving students' learning performance in science courses	Natural science course	Sixth graders of an elementary school
HwangYW2013	Hwang et al. (2013)	A concept map-embedded educational computer game for improving students' learning performance in natural science courses	Natural science course	Sixth graders of an elementary school
HwangSHYH2013	Hwang et al. (2012b)	A knowledge engineering approach to developing educational computer games for improving students' differentiating knowledge	Natural science course	Sixth graders of an elementary school

HwangHC2014	Hwang et al. (2014)	Improving learning achievements, motivations and problem-solving skills through a peer assessment-based game development approach	Natural science course	Sixth graders of an elementary school
Akcaoglu2014	Akcaoglu (2014)	Learning problem-solving through making games at the game design and learning summer program	Computer Science	Middle school students
HwangCC2015	Hwang et al. (2015)	A contextual game-based learning approach to improving students' inquiry-based learning performance in social studies courses	Social science course	Sixth graders from an elementary school
HungSY2015	Hung et al. (2015)	The benefits of a challenge: student motivation and flow experience in tablet-PC-game-based learning	Mathematics	Second-grade students
HamariSRCAE 2016	Hamari et al. (2016)	Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning	Quantum physics and engineering dynamics course	High school students and undergraduate mechanical engineering students
HwangHLH20 17	Hwang et al. (2017)	Interaction of problem-based gaming and learning anxiety in language students' English listening performance and progressive behavioral patterns	English as a foreign language	Ninth-grade students
SungHLH2017	Sung et al. (2017)	Experiencing the Analects of Confucius: An experiential game-based learning approach to promoting students' motivation and conception of learning	Analects of Confucius in a Chinese course	Fifth graders from an elementary school
KaoCS2017	Kao et al. (2017)	Customizing scaffolds for game-based learning in physics: Impacts on knowledge acquisition and game design creativity	Physics	Junior high school
YangQ2018a	Yang & Quadir (2018)	Effects of Prior Knowledge on Learning Performance and Anxiety in an English Learning Online Role-Playing Game	English as a foreign language	Sixth graders from an elementary school
YangLC2018	Yang et al. (2018)	Effects of anxiety levels on learning performance and gaming performance in digital game-based learning	English as a foreign language	Fourth graders from an elementary school
Ge2018	Ge (2018)	The impact of a forfeit-or-prize gamified teaching on e-learners' learning performance	English as a foreign language	First-year adult e-learners from an e-learning college
YangQ2018b	Yang & Quadir (2018)	Individual differences in an English learning achievement system: gaming flow experience, gender differences and learning motivation	English as a foreign language	Elementary school students
ZainuddinSHC 2020	Zainuddin et al. (2020)	The role of gamified e-quizzes on student learning and engagement: An interactive gamification solution for a formative assessment system	Not specified	Junior high students
VanbecelaereV CSRD2020b	Vanbecelaere et al. (2020)	The effects of two digital educational games on cognitive and non-cognitive math and reading outcomes	Math and reading skills	First graders from an elementary school

SailerS2020	Sailer & Sailer (2020)	Gamification of in-class activities in flipped classroom lectures	Not specified	University students
HuangH2021	Huang & Hew (2021)	Using Gamification to Design Courses: Lessons Learned in a Three-year Design-based Study	Undergraduate Introductory Information Management Course	Undergraduate Introductory Information Management students
Hossein-mohandTGHC2021	Hossein-Mohand et al. (2021)	Analysis of the Use and Integration of the Flipped Learning Model, Project-Based Learning, and Gamification Methodologies by Secondary School Mathematics Teachers	Mathematics	Mathematics teachers