Wang and Yi *Research and Practice in Technology Enhanced Learning* (2025) 20:37
https://doi.org/10.58459/rptel.2025.20037

Research and Practice in Technology Enhanced Learning

RESEARCH Free and Open Access

A bibliometric analysis of digital game-based learning in educational contexts

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Abstract

As an emerging topic, digital game-based learning holds great significance as it revolutionizes traditional modes of education by harnessing engagement and enhancing learning outcomes. We bibliometrically analyzed the current studies of digital game-based learning, aiming to explore the key topics and domains of the trend that may inspire further research and innovations. This study employed VOSviewer to explore the top ten authors, sources, organizations, and countries and established a citation network using clustering techniques in CitNetExplorer to visualize the results. Based on the research, it is found that motivation maintenance, in-game feedback, and post-game motivation are important factors impacting sustainable digital learning. This study proposes a framework comprising three elements—Preparation, Process, and Settlement—aligned with different stages of digital gaming. By integrating factors affecting learners with gaming elements, the framework aims to enhance the effectiveness and sustainability of digital learning. Future research could involve implementing game designs based on our proposed framework to evaluate its effectiveness. Additionally, there is potential to integrate AI to promote learner experiences and optimize learning outcomes.

Keywords: Digital game-based learning, Bibliometric analysis, Game design

Introduction

Game-Based Learning (GBL) is defined as learning that is facilitated by the use of a game, featuring challenging goals, interaction and feedback (Adipat et al., 2021; Whitton, 2012). GBL excels in its ability to create immersive environment and deliver interactive experiences, that both can contribute to the effectiveness of learning. And it has been applied into various educational contexts as an optimized teaching approach. Early research has explored diverse applications, from enhancing engineers' in Computer-Aided Design (CAD) proficiency to fostering immersive science learning environments (Brown

et al., 2018; Prensky, 2001). The integration of digital games and education has received increased attention in various fields, particularly in STEM (Science, Technology, Engineering and Mathematics) education (Hung et al., 2018). Additionally, the application of digital games in language learning has been highlighted for its capacity to create engaging language environments while reducing anxiety and enhancing language interaction (Reinders & Wattana, 2015).

GBL differs Digital Game-Based Learning (DGBL) from their medium of learning. DGBL is a broad term that is often used to describe the relationship between games played on computers, gaming consoles, and mobile devices and various learning processes or outcomes (Aguilera & de Roock, 2022). While game-based learning has been extensively reviewed in academic studies (Ekin & Gul, 2022; Krath et al., 2021; Swacha, 2021), there is a dearth of comprehensive research on digital game-based learning. Though existing literature reviews have updated the advancements in this field, for instance, bibliometric studies to delve into status quo and trends of research (Baalsrud Hauge et al., 2022; Karagöz & Ates, 2022), and meta-analyses to investigate the effectiveness of DGBL on learning in different subjects (Chen et al., 2018; Chiu et al., 2012; Tsai & Tsai, 2018), a gap exists in the overall review of digital game-based learning in educational contexts. Supported by the bibliometric results, we investigated the research paths, analyzed and classified the research topics and configured a framework for digital game design.

Our analysis facilitated by CitNetExplorer and VOSviewer aims to offer a comprehensive overview on digital game research within educational contexts. By integrating visualization techniques with citation network analysis, this study reveals the trajectory of related studies, the main application scenarios, and its recent trends. CitNetExplorer, featuring powerful citation matching algorithms, is capable of processing large citation networks as the start of the analysis and transitive reduction. While VOSviewer offers alternative visualization modes to present data from various perspectives, a principled combination of the two by drawing upon the advantages of both can enhance depth and breadth of the research and provide a cross-validation of findings. We show the differences between other bibliometric studies on the same topic in Table 1. We also propose an extended framework that covers critical components of digital game design and influential factors on learners in education to guide how game designers and implementers develop and apply digital games to new educational contexts.

Of all the studies, the Input–Process–Outcome (IPO) framework, Motivation, Volition, and Performance (MVP) and the Attention, Relevance, Confidence and Satisfaction (ARCS) model, have laid the groundwork for understanding the key elements influencing digital game-based learning (Huang et al., 2010; Huang et al., 2014; Keller, 1983). However, there is still a need for a synthesized framework for digital games that addresses learners' subjective experiences and optimizes learning outcomes. Such an integrated

framework that combines the influential factors on learners and elements of gaming may contribute to a more sustained and personalized game design, representing the future potential of this field.

Literature review

Bibliometric studies

Our bibliometric study employs a synergetic approach by combing VOSviewer (van Eck & Waltman, 2014b) and CitNetExplorer (van Eck & Waltman, 2014a). The implementation of VOSviewer is illustrated in Figure 2 to Figure 5. The most common

Table 1 Our study that differs from previous bibliometric studies

Articles	Authors	Content and focus	Difference
State of research on gamification in education: a bibliometric survey	(Swacha, 2021)	It highlights the main characteristics of gamification in education, underlying growing interest and research output in the area and investigates the preferred channels for disseminating research. It also recognizes leading scientific institutions, significant contributors, and collaboration patterns among researchers.	We go beyond the basic bibliometric results such as keywords, authors and institutions etc., and further investigate the research paths and dig into the topics.
Bibliometric analysis of game-based researches in educational research	(Ekin & Gul, 2022)	The research analyzes geographic distribution of related studies, identifies popular journals and conferences, prominent research organizations and scholars, and the researcher collaborations. The study finds that learning motivation and effectiveness of games are the most frequently recurring topics.	Based on our findings in the review of learning factors impacting digital game-based learning outcomes, we explore the game mechanism in the learning process, and construct a game design framework by synthesizing motivation theories and others.
A bibliometric analysis of gamification research	(Trinidad et al., 2021)	The research overview identifies key authors and their significant research contributions. The results reveal that the research fronts and internal relationships among articles, highlighting emerging trends. They have also traced the evolution and dynamic nature of the discipline, demonstrating how it has developed over time as a scientific field.	We further investigate digital game-based learning and explore how to facilitate game design that enhances the effectiveness of games in education.
The use of gamification in education: a bibliometric and text mining analysis	(Martí-Parreño et al., 2016)	The research pinpointed key authors and organizations, prominent subjects, and the evolution of knowledge trends. Results show an increasing scholarly focus on four main areas: (i) efficacy, (ii) adoption, (iii) involvement, and (iv) communal interaction.	Based on these themes, we explore how digital games affect learning, focusing on factors such as motivation, and interaction in learning and effectiveness.

occurrence keywords are displayed in Figure 2. They visually reveal the popular topics. Figure 3 demonstrates the clustered results of CitNetExplorer, by classifying articles into different groups according to their citation relationship. It shows the most recent and pioneering findings as references for further exploration. Figures 4 and 5 are the longest paths selected, and by reviewing and analyzing the previous study, the topics transferred from the pioneering articles and recent findings can be identified.

Compared with other review methods (Table 2), such as systematic review, bibliometric review visually demonstrates the connections of different studies on the same research path (usually by their citations) and displays the research focus, which provides insight into the topics and implications for further studies.

Previous studies

There is a substantial body of reviews on gamification and game-based learning. Gamification involves using game elements, such as points, badges, game mechanisms (leaderboards), and challenges, in non-game contexts to engage and motivate learners (Deterding et al., 2011). Game-based learning emphasizes the educational content

Table 2 Differences between bibliometric studies and other methods of review

Types of reviews	Characteristics	Differences	Strengths of bibliometric study
Systematic reviews	It collates empirical evidence from numerous articles to address a clearly defined research inquiry.	A bibliometric analysis gathers empirical data from a wide selection of articles, where the question is not set but remains adaptable.	Utilizing advanced information technology, bibliometric studies can retrieve articles efficiently, analyze citation patterns and publication metrics, revealing the structural and dynamic characteristics of research fields.
Scoping reviews	The process involves evaluating the abundance of articles in a specific field, sorting them into categories, and pinpointing any areas that lack sufficient coverage.	It evaluates the range of existing articles in a particular field, categorizes them into groups, and identifies any areas that lack coverage.	A bibliometric analysis can generate fairly uniform groups of articles within its citation network.
Literature reviews (narrative reviews)	Literature reviews offer a comprehensive summary of existing knowledge on a specific subject.	Bibliometric studies delve deeper into specific fields by quantitatively analyzing publication data, uncovering patterns, trends, and relationships.	Driven by data, a bibliometric study not only facilitates the creation of high-quality content but also traces patterns and trends, enhancing the depth and reliability of the research.

delivered within a game environment, aiming to facilitate learning through interactive gameplay (Whitton, 2012). Although related, the two terms serve different educational purposes. While game-based learning integrates games as a core part of the learning process, gamification make use of game elements in non-game environments to encourage positive behavior (Gavrilova et al., 2021). A plethora of research note gamification's positive influence on student motivation and engagement, but its effect on performance remains less clear. In healthcare, gamification enhances training, promotes healthy habits, and supports health condition self-management (Trinidad et al., 2021). Despite the current studies that highlight the benefits of gamification, such as heightened motivation and interest, the exploration of potential negative consequences including anxiety, frustration, and social comparison, is still limited (Martí-Parreño et al., 2016).

GBL has been extensively documented in educational fields, and its impact on learners, such as motivation, emotions, and learning outcomes, has been widely researched (Martí-Parreño et al., 2016). A meta-analysis reveals that game-based science learning significantly benefits students, enhancing their scientific knowledge through practical learning and gaming mechanisms (Tsai & Tsai, 2020). Empirical research related to digital game-based learning have been extensively conducted on the major disciplines of STEM. One of the pioneering studies explore the effect of digital game on enhancing engineers' in CAD proficiency (Prensky, 2001). Later, various forms of digital games were created for learning science knowledge and skills by diverse methods for assessment (Brown et al., 2018).

The studies on digital game-based learning prominently focus on improving learning outcomes, engagement and motivation through digital games (Licorish et al., 2018). The diverse applications of DGBL hold substantial implications for educational practice, suggesting that digital games can be powerful tools for improving learning experiences across different subjects and contexts (Licorish et al., 2018). Throughout widespread application fields, previous literature has continually updated the studies on digital game-based learning. Various researchers have summarized advances in promoting digital game-based learning in educational contexts (Chiu et al., 2012; Tsai & Tsai, 2018; Wang et al., 2022). Digital game-based language learning geared the attention to immersive language learning environment, methods of relieving anxiety, and high frequency of interaction of the target language (Hung et al., 2018). A scoping review of DGBL foresaw the large potential of mobile digital games in English language learning (Xu et al., 2020).

Theoretical backgrounds and framework

Various subjective factors have been identified in previous research that significantly impact learning performance. The review underscores how game mechanisms impact affective and motivational outcomes, behavioral outcomes, and learning outcomes,

illustrating the ways games influence learners (Krath et al., 2021). The ARCS model introduces a motivation framework for effective learning, including factors of attention, relevance, confidence and satisfaction (Keller, 1983). Huang et al. (2010) reveal a significant relationship between the motivation and the feedback of the ARCS model, and the interaction of intrinsic motivation and extrinsic incentives in motivating students. Huang et al. (2014) created the Input–Process–Outcome (IPO) Model with a diagnostic mechanism prompt, highlighting the positive experience by students engaged in learning through digital game.

There are several other frameworks on designing digital games. Cheng et al. (2017) revealed that background story, AI and adaptability, interaction, feedback, and reporting are important facilitators in gamification. Game elements, i.e., the game mechanisms, narrative and aesthetics elements, could trigger cognitive experience of players in gaming (Alexiou & Schippers, 2018).

Based on the above theories and frameworks related to the game experience, we configured a framework for designing digital games: Preparation, Process and Settlement (PPS) by highlighting the interactive mechanisms within the game and learning feedback.

Research purposes and questions

Our study aims to analyze the use of digital games in educational contexts and identify the important factors in the design of digital games for learning. The research questions are listed as follows:

RQ1: What are the top keyword items, authors, organizations, and countries in the studies on digital game-based learning in education?

RQ2: What are the primary applications of digital game-based learning in education contexts?

RQ3: What are the popular research issues in the studies on digital game-based education?

RQ4: How does digital game-based language learning evolve from learning by game?

RQ5: What factors should be considered for sustainable influence on learning when the digital game is integrated with education?

Methods

Literature search analysis from Web of Science

Web of Science (WOS) is selected as the major data source for its various analytical tools for bibliometric analysis, rigorous selection criteria and broad subject indexing that is suitable for interdisciplinary research topics.

We searched literature from Web of Science Core Collections. Four Editions, chosen for their high relevance to the research topics: Science Citation Index Expanded (SCIE, 2013

to present), Social Sciences Citation Index (SSCI, 2006 to present), Arts and Humanities Citation Index (A&HCI, 2008 to present), and Emerging Sources Citations Index (ESCI, 2017 to present). Options of Current Chemical Reactions (1985 to present) and Index Chemicus (1993 to present) from the Web of Science were excluded for their lack of publications. In order to escape unexpected academic issues like retractions of included articles, we decided to exclude the articles that are still in early access or early version.

The literature search involved typed keywords such as digital game-based (Topic) AND interact* OR learn* OR educat* OR teach* (Topic) on the Web of Science. The "Analyze Results" function was utilized to present an analysis of publication trends, categories (subjects and research areas), and publication titles (journals) of the selected literature. The initial part of the research procedures focused on retrieving essential bibliometric data, followed by an examination of the publication trend over the past 17 years (the longest retrospective period accessible on the website). In addition, we identified the most frequently published research categories and journals.

The WOS website reported the most frequently published research categories and journals, display the publication and citation trends of the topics by the citation network (Figure 1), and the research fields or categories. The visualized results of the data selected were processed in VOSviewer (Figure 2) and CitNetExplorer (Figures 3 to 5).

Analysis by Visualization and CitNetExplorer

We exported the full records and the cited references of the search results as plain text files for visualized analysis. The file would be processed by VOSviewer for further analysis. We excluded 56 documents of the early access type for further bibliometric analysis. Then the text file of the full records and cited references was processed and analyzed in VOSviewer (van Eck & Waltman, 2014b) and CitNetExplorer (van Eck & Waltman, 2014a). VOSviewer could visualize information from the literature to infer the connections between authors, keywords, countries and organizations. For each analytical project, we looked for the top occurrence items and frequencies that were most cited. Meanwhile, the software provided lists that counted the citations and occurrences of authors, keywords, countries and organizations.

Regarding the visualization of citations, we collected the top 10 authors, countries and organizations to show the representative publisher of this topic. We collected the top 25 keyword items measured by occurrences. With CitNetExplorer's "clustering" function, analysis of research was conducted so that studies directly connected could be clustered in the same cluster. Citation network analysis was also allowed, by which the longest paths were retrieved from the most cited or recent studies. The relationship would form a citation network, transmitting the original ideas to the latest research through multiple stages of the citation. Therefore, this function would be helpful to identify the theoretical bases and

newest achievements in this area. However, though current studies have directly cited the pioneering publications, the most recently published research was not in 2023. Such paths could not generate significantly enlightening interpretations of the citation network. So, analyses of the most cited and relatively new publications would be connected and analyzed to reveal the advancements in the research topics.

Results

Literature search and trends

We've got 853 publications based on the search result by November 15, 2023, from which 56 early-accessed papers were excluded. For all these results, Web of Science could reveal the year-based publication trends. As demonstrated in Figure 1, we selected to display the publication number in the past 15 years, because studies before 2008 were too few to be displayed. The current climax was recorded for 2022 (N = 145). In the year 2023, 143 publications were published till the time of data collection. The number of publications sharply increased around 2020 and kept increasing. We then analyzed the Web of Science categories to which these results belonged. The top ten published categories were Education Educational Research (N = 507, 59.437%), Computer Science Interdisciplinary Applications (N = 104, 12.192%), Psychology Multidisciplinary (N = 43, 5.041%), Computer Science Information Systems (N = 41, 4.807%), Linguistics (N = 35, 4.103%), Education Scientific Disciplines (N = 33, 3.869%), Public Environmental Occupational Health (N = 33, 3.869%), Psychology Experimental (N = 24, 2.814%), Environmental Sciences (N = 22, 2.579%) and Health Care Sciences Services (N = 21, 2.462%).

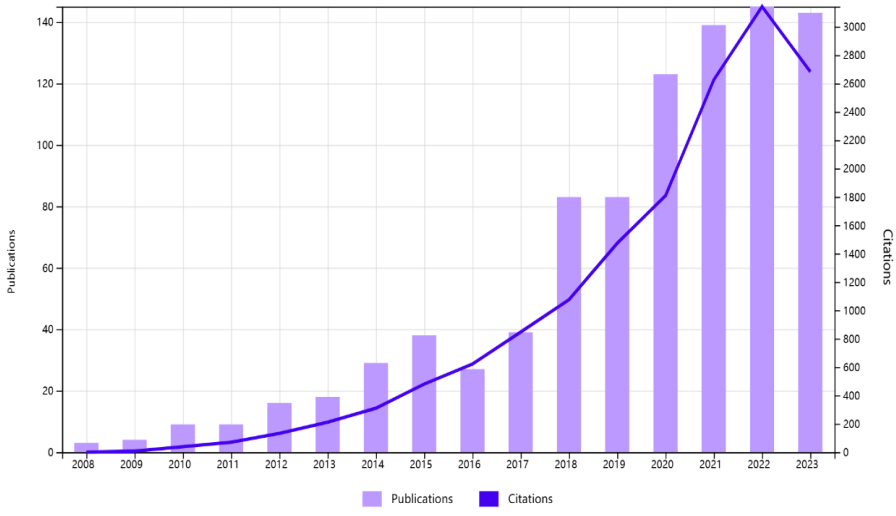

Fig. 1 The year-based trend of selected publications and citations

The top ten journals were Computers and Education (N = 57, 17.485%; SSCI and SCIE), Educational technology research and development (N = 30, 9.202%; SSCI), Journal of Computer Assisted Learning (N = 23, 7.055%; SCI), Education and Information Technologies (N = 21, 3.067%, SSCI), Interactive Learning Environments (N = 21, 6.442%, SSCI), Computers in Human Behavior (N = 20, 6.135%; SSCI), Educational Technology and Society (N = 20, 6.135%; SSCI), Education Sciences (N = 18, 5.521%; SCI), Journal of Educational Computing Research (N = 18, 5.521%; SSCI) and British Journal of Educational Technology (N = 17, 5.215 %; SSCI). All ten journals were found indexed in the Scopus source list. The related journals were included in Science Citation Index (SCI), SSCI, A&HCI, SCIE and ESCI journals. The number of publications involved was 326.

The results indicated that relevant studies were distributed widespread across various publication journals while focusing on computer field, as evidenced by the modest percentage of publications per journal. The covered subjects in these journals encompassed Education, General Computer Science, Computer Science Applications, Human-Computer Interaction, and Arts and Humanities. Notably, the top ten journals predominantly consisted of high-impact publications, which was supported by their indexing records.

It is inferred from Figure 1 that the trend of included publications and citations developed, which displays that the studies on digital game-based learning in education have become increasingly popular since 2008. The number of related studies grew stably between 2009 and 2019 and then rose quickly in 2020. The period from 2020 to 2022 witnessed lots of publications related to digital games in education. As time advanced, the number of citations was still increasing in 2023 and showed a trend of transcendence, which meant that the topic of digital game-based learning in education remained popular.

Research question

RQ1: What are the top keyword items, authors, organizations, and countries in the studies on digital game-based learning in education?

To answer the second research question, we first displayed the Clusters of keywords (Figure 2), and calculated the top ten cited authors, sources, organizations, and countries through VOSviewer (Table 3).

VOSviewer has visualized 118 keywords from inclusion-refined results. As illustrated by the various colors in Figure 2, the keywords were organized into ten clusters. Cluster 1 (24 items), Cluster 5 (18 items), and Cluster 6 (17 items) occupied the central part with larger nodes, indicating their higher frequency of occurrence. Cluster 1 included keywords like “student,” “digital game,” and “video game.” Cluster 5 (18 items) comprised terms such as “game-based learning,” “gamification,” and “computer games.” Cluster 6 featured keywords like “motivation,” “digital game-based learning,” “performance,” and

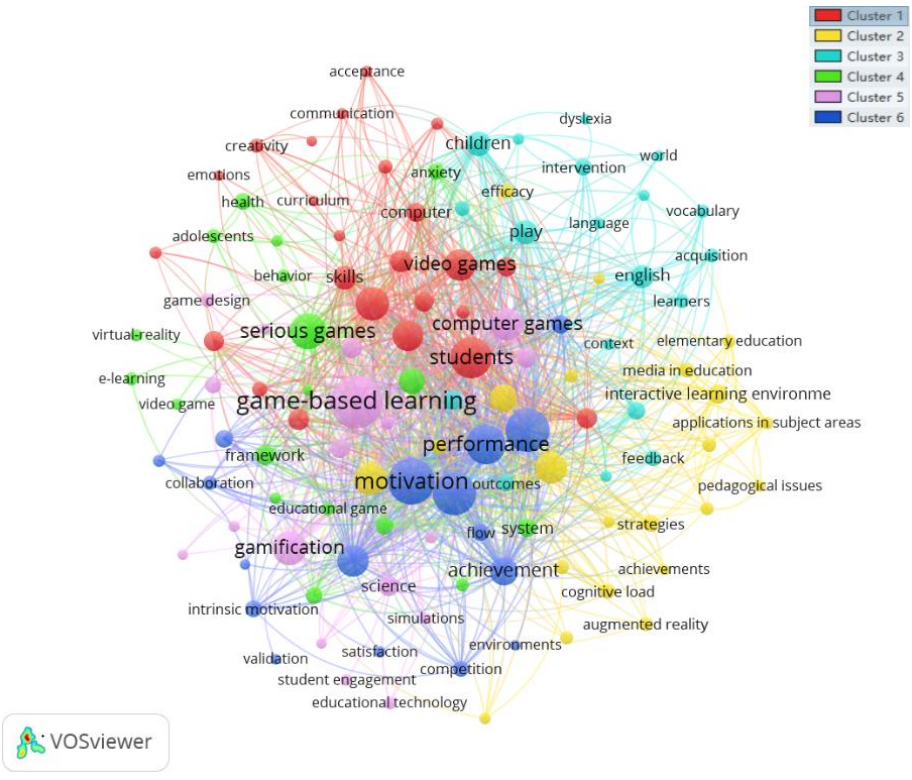

Fig. 2 Keywords clustering by VOSviewer

"education." Other noteworthy nodes representing keyword items encompassed "impact" (Cluster 2), "serious game" (Cluster 4), and "play" (Cluster 3).

As shown in Table 3, the top ten authors on this topic are Hwang, G. J., Marina, P., Yang, J. C., Wu, P. H., Jan, V. L., Tsai, C. C., Chen, C. C., Wang, S. Y., Yang, L. H., and Erhel, S. The top ten sources are Computer & Education, Computers in Human Behavior, Educational Technology Research and Development, Journal of Computer Assisted Learning, Educational Technology and Society, Interactive Learning Environments, British Journal of Educational Technology, Computer Assisted Language Learning, Journal of Cultural Heritage, Journal of Educational Computing Research. The top ten organizations were as follows, National Taiwan University of Science and Technology, University of Thessaly, National Taiwan Normal University, National Central University, National Cheng Kung University, Coventry University, National Taiwan, National Taiwan University, Ghent University, National Taipei University of Education and University Rennes 2. The top ten countries were China, USA, Greece, England, Netherlands, France, Finland, Spain, Belgium, and Germany.

Table 3 Top ten sources, authors, organizations, and countries

N	Cited sources	Citation	Link	N	Cited author	Citation	Link
1	Computer and Education	4315	708	1	Hwang, G. J.	1584	1184
2	Computers in Human Behavior	1143	134	2	Marina, P.	809	196
3	Educational Technology Research and Development	722	213	3	Yang, J. C.	499	526
4	Journal of Computer Assisted Learning	703	221	4	Wu, P. H.	460	184
5	Educational Technology and Society	593	147	5	Jan, V. L.	331	214
6	Interactive Learning Environments	463	146	6	Tsai, C. C.	330	324
7	British Journal of Educational Technology	433	127	7	Chen, C. C.	322	111
8	Computer Assisted Language Learning	383	68	8	Wang, S. Y.	317	124
9	Journal of Cultural Heritage	258	5	9	Yang, L. H.	317	124
10	Journal of Educational Computing Research	237	88	10	Erhel, S.	305	160
N	Organization	Citation	Link	N	Country	Citation	Link
1	National Taiwan University of Science and Technology	2241	938	1	China	6066	1598
2	University of Thessaly	810	156	2	USA	2438	633
3	National Taiwan Normal University	748	380	3	Greece	1300	228
4	National Central University	685	402	4	England	1033	186
5	National Cheng Kung University	631	212	5	Netherlands	810	146
6	Coventry University	466	33	6	France	672	137
7	National Taiwan University	405	121	7	Finland	627	231
8	Ghent University	398	140	8	Spain	613	201
9	National Taipei University of Education	389	152	9	Belgium	518	130
10	University Rennes 2	319	133	10	Germany	455	215

RQ2: What are the primary applications of digital game-based learning in education contexts?

The exported literature was clustered in different groups based on their citation network in CitNetExplorer to reveal the primary applications of digital game-based learning in educational contexts. The CitNetExplorer results delineated two principal applications (Group 1 - 2) of digital games within educational environments while the other six clusters (Group 3 - 8) contained a small number of literature and uneven topics, making them difficult to classify. Although the possibility of ambiguous clustering results existed, they involved interdisciplinary references and each identified cluster highlighted a distinct emphasis on varied educational contexts.

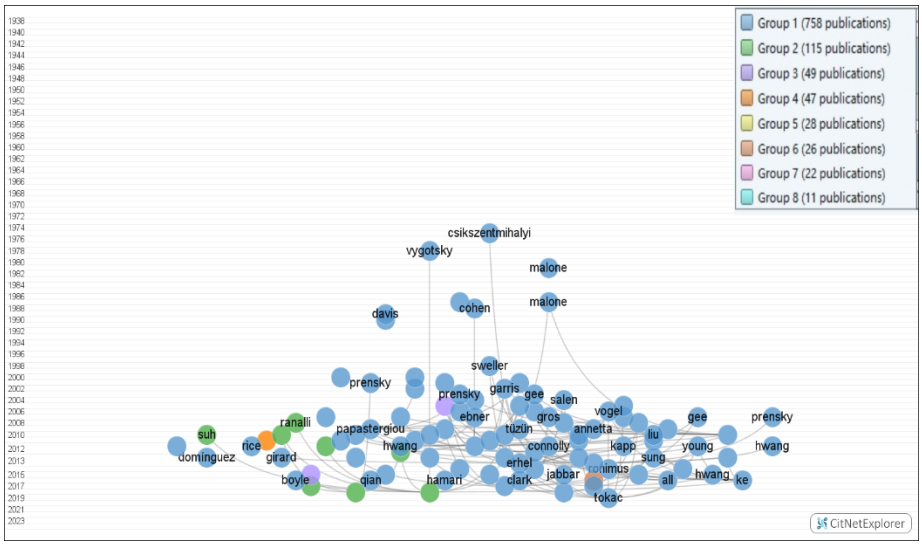

Fig. 3 The literature clustering results by CitNetExplorer

Group 1 focuses on the impact of digital games on teaching and learning across various subjects, such as computer science, math, and science. It examines the pedagogical role of digital games in the classroom and explores the acceptance, interest, and motivation for digital game-based learning among students and teachers. Group 2 primarily studies the effects of digital games on language learning, including vocabulary acquisition, foreign or second language learning, and practices that enhance language competence, such as communication.

The clustering results (Figure 3) did produce well-defined groups of the literature because some studies were hard to define their fields according to their research topics, and studies that were not clustered account for a considerable proportion. Therefore, this study only classified the identification of the two primary application contexts of digital game-based learning in education:

(1) Evaluation of DGBL on learning

(2) Language learning

RQ3: What are the popular research issues in the studies on digital game-based education?

Table 4 presents the most prevalent research issues in studies on digital game-based education. The paths of frontier research in Group 1 were analyzed. As shown in Figure 4, the longest paths are highlighted and it is pioneered by Prensky (2001) who proposed that today's students are born in the digital age, which has profoundly influenced their engagement with the world.

Table 4 Prominent research issues in digital game-based education

	Focus	Topics	Keywords	Number	Overall
Group 1	Digitally empowered learning	Impact on learners	Learning performance	20	79
			Motivation	47	
			Self-efficacy	3	
			Emotion	9	
Group 2	Language learning	English language ability	Vocabulary	18	31
			Grammar	2	
			Reading	2	
		Language acquisition	Acquisition	9	
RQ 4	Evolutions of digital game-based language learning	Game-based learning	Gamification, serious game	73	388
		Digital game-based learning	Digital game, mobile game	268	
		Digital game-based language learning	Language learning	47	

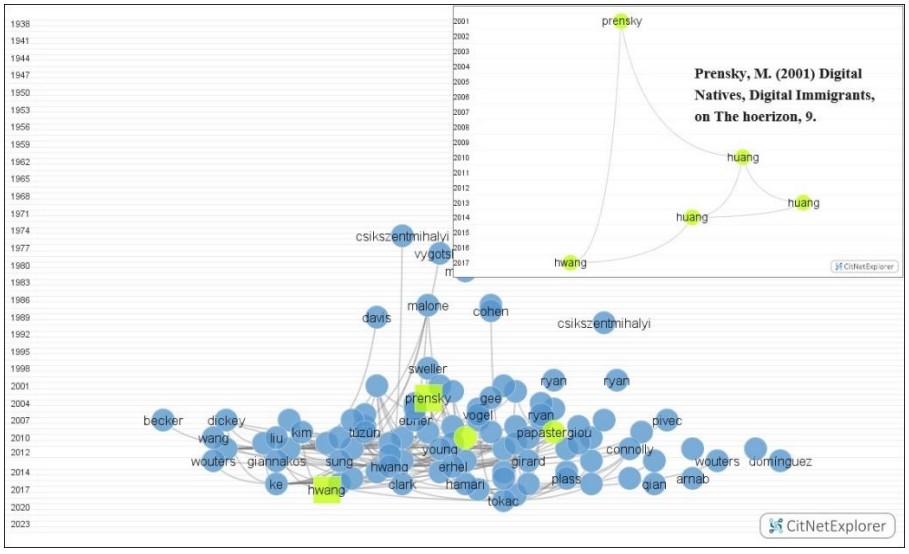

Fig. 4 Longest citation paths in Group 1

The selected publications around 2014 analyzed the impact of DGBL in the learning process, laying ground for the design of DGBL. Huang et al. (2010), grounded in his theory of MVP, confirmed the influential role of the motivation process in feedback, which allows learners to assess their capability to undertake tasks and evaluate their performance efforts. Huang et al. (2013) suggest that the cognitive effort invested can provide feedback at the end of the learning cycle, providing students with satisfaction.

Huang et al. (2014) revealed that integrating diagnostic and prompt models into games can reduce anxiety and enhance learning performance. Hwang et al. (2017) found that the

game-based teaching method is beneficial for students' academic performance and motivation. Research showed that the component influences satisfaction most in the motivation and the rewards. Therefore, the design of DGBL should focus more on the motivation, diagnostics and positive feedback to improve learners' experience.

Group 2's recent studies on DGBL in language learning were analyzed through their longest research paths, highlighted in red in Figure 5. This analysis starts with the publication of Yip and Kwan (2006), which showed that students preferred online vocabulary learning through digital games than conventional methods. Research by Chiu et al. (2012) suggested that cooperative and background story-implanted games yield a significant effect by their language interaction, which is a crucial element in language learning.

From a meta-analysis study, Tsai and Tsai (2018) reported that digital games effectively motivate students to learn second language vocabulary. Based on Flow Theory, Chen et al. (2018) indicated that DGBL should be interesting and challenging so that games can effectively facilitate vocabulary learning. They found this impact to be consistent regardless of age or language background. Research by Hung et al. (2018) suggested that digital games have the potential to enhance learning outcomes, especially for students with higher anxiety levels.

A review by Zou et al. (2021) suggested that digital games benefit vocabulary learning, reading and listening comprehension, and pronunciation skills. It was noted that digital games increase motivation and engagement. Acquah and Katz (2020) found that digital learning games benefit language acquisition, short-term memory, and participatory behavior, even without teacher intervention. Junttila et al. (2022) showed that game

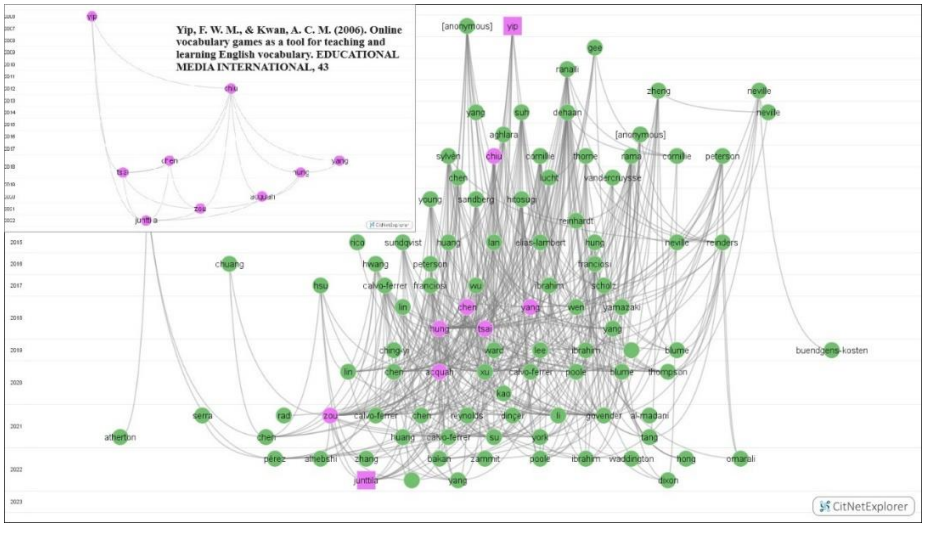

Fig. 5 Longest citation paths in Group 2

interventions are more effective for children's speech learning than non-game methods. In summary, DGBL has been widely recognized as positively impacting on various aspects of language learning, including vocabulary acquisition, reading and listening comprehension, learner motivation, engagement, anxiety mitigation, and interactive capabilities.

RQ4: How does digital game-based language learning evolve from learning by game?

The longest paths from Group 2 demonstrate the evolution and empirical support for digital game-based language learning (DGBLL). Table 4 also displays relevant topics of the evolutions of DGBLL. Before the widespread integration of digital game and language learning, empirical research related to digital game-based learning have been extensively conducted, especially on the major disciplines of STEM (Hung et al., 2018). One of the pioneering studies explored the effect of digital game on engineers' CAD proficiency (Prensky, 2001).

DGBLL originated from combining English as a Second Language (ESL) learning with computers (Miller & Hegelheimer, 2006), has shown the potential to improve students' competence and knowledge with dynamic, interactive game contexts (Qian & Clark, 2016). For instance, a simulation and role-playing game named Space Station Leonis, combines simulation and role-playing to foster students' sense of identity and civic responsibility (Chee, 2007). Egbert and Hanson-Smith (1999) suggested using SimCity to promote ESL. DGBLL has proven particularly valuable (Young & Wang, 2014) by creating engaging language environments, reducing anxiety, and enhancing language interaction (Hung et al., 2018).

The effects of DGBLL have been extensively discussed by reviews. Liu et al. (2002) highlighted its potential to enhance self-confidence, occupation preparation, and language proficiency in foreign language education by examining research on computer-aided language learning. A meta-analysis indicates that the fusion of digital games with vocabulary learning leads to a notable increase in student learning efficiency (Tsai & Tsai, 2018). Yu (2018) found that interactive language learning games significantly enhance English vocabulary acquisition, performing better than traditional methods. Peterson (2016) reviewed research on large-scale multiplayer online role-playing games (MMORPGs) and concluded that these games can enhance language acquisition, offering learners the chance to engage with the target language through associated language communities.

Over the past few decades, digital games have been employed as a learning tool across various subjects, including English (Smith et al., 2013). Numerous studies support the effectiveness of digital games in language learning. Chiu et al. (2012) found a moderate effect of digital games on foreign language learning. However, it remains unclear whether

game elements themselves enhance learning or if they increase motivation and practice time, thereby improving outcomes (Junttila et al., 2022). This poses a promising topic for exploring the effectiveness of game-based language learning in the future. The Internet connects users from different cultures. However, it lacks studies on games that address cross-cultural topics to enhance cross-cultural competence. Although evidence supports the effectiveness of digital games in learning, future research should explore how digital learning games can improve social and cultural outcomes (Acquah & Katz, 2020).

RQ5: What factors should be considered for sustainable influence on learning when the digital game is integrated with education?

Group 1 also revealed some issues in the process of designing digital games and implementation of interdisciplinary applications. In Group 2, various research studies have been done to estimate the effect of digital game-based learning through different frameworks. Keller (1983) put forward the ARCS model that was used to measure various subjective factors of learners, and motivation is a critical factor in the design of DGBL (Astleitner & Wiesner, 2004). However, relying solely on motivational elements is insufficient for optimizing learning outcomes. Garris et al. (2002) stressed the importance of ongoing engagement strategies in DGBL implementations to sustain interest and involvement over time, highlighting how iterative game cycles sustain learning motivation.

Additionally, Huang et al. (2010) advocate for integrating considerations of motivational processing in DGBL to monitor learners' cognitive load during gameplay. It is noted that motivation and cognitive load factors is crucial for optimizing learning experiences. Astleitner and Wiesner (2004) caution against relying solely on intrinsic motivation in DGBL, mentioning the importance of managing motivation consumption to sustaining learners' engagement. Newby and Alter (1989) suggested a comprehensive evaluation of both intrinsic and extrinsic motivation for effective DGBL design, to explore functioning mechanisms. Chou and Lu (2022) proposes a game-based learning system with dynamic difficulty adaptation to provide personalized challenges during gameplay, ensuring equitable opportunities for all students to progress.

Astleitner and Wiesner (2004) stressed a concept that Flow Theory, an engaging learning experience arises when challenge matches the learner's ability. Games that feature diagnostic and prompting systems can effectively promote motivation and performance and reduce anxiety during gameplay (Huang et al., 2014). Effective digital games also provide timely feedback to meet the needs of players, achieving continuous learning (Sweetser & Wyeth, 2005). Alexiou and Schippers (2018) discuss the importance of a negative feedback mechanism to maintain balanced competition and sustained engagement in DGBL environments such as the options for dynamic difficulty adjustment.

Table 5 Inspired content in digital design model

Publications	Inspired content
(Keller, 1983)	ARCS Model
(Astleitner & Wiesner, 2004)	Motivation Maintenance
(Newby & Alter, 1989)	External Incentives
(Huang et al., 2014)	Prompt Mechanism
(Garris et al., 2002)	Game Loop
(Sweetser & Wyeth, 2005)	Adjustable Difficulty
(Alexiou & Schippers, 2018)	Aesthetics Design

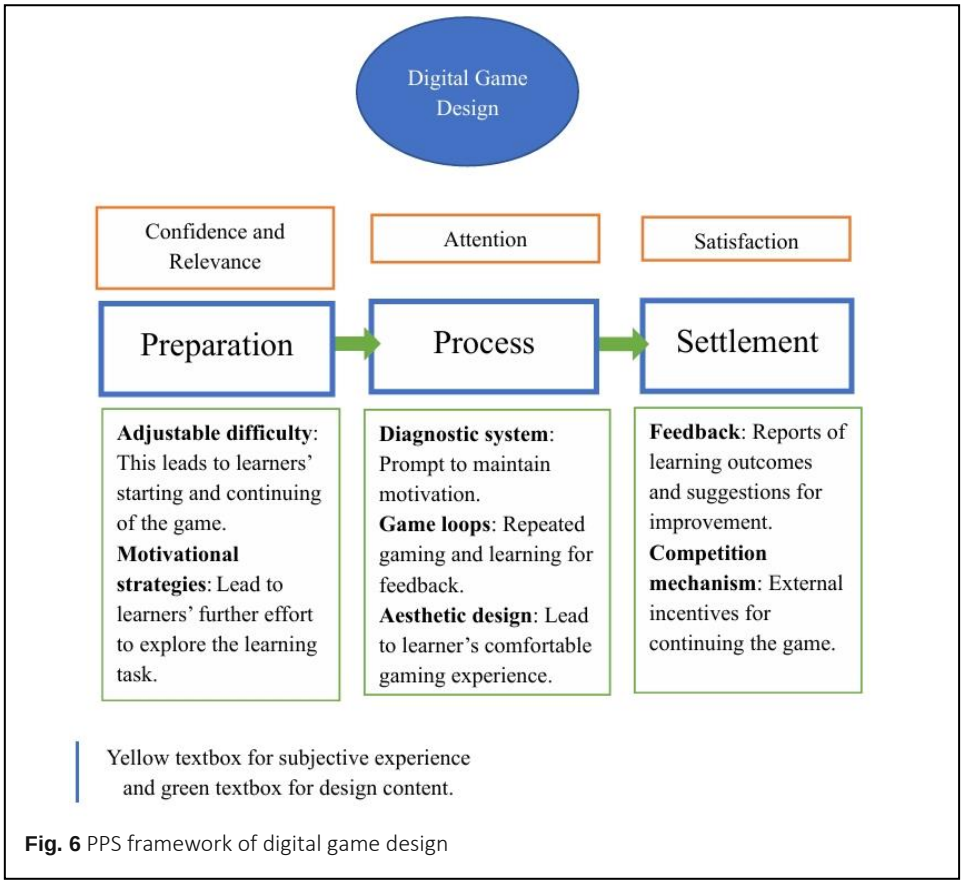

Fig. 6 PPS framework of digital game design

The author also examined theories of game design which usually contain gaming elements and analysis of user experience. The game mechanisms, narrative and aesthetics elements, could influence cognitive experience of players in gaming (Alexiou & Schippers, 2018). Game design perspectives typically consider both the creator and player viewpoints. The MDA model pioneered formal game design by breaking down games into Mechanics, Dynamics, Aesthetics (Hunicke et al., 2004). This model has been expanded upon by subsequent frameworks such as the DPE model—Design, Play, Experience—which adds layers of focus on content and player experience (Winn, 2009). Hybrid models such as

DPE combine elements from various game design frameworks aiming to enhance educational objectives and user experience (Pereira de Aguiar et al., 2018). These models provide the collaborative instructions on designing instructional content, interactive experiences, and optimizing learning in educational games.

Drawing from research on frameworks and game design theory, the design of digital games hinges on the interaction between the game and learners. Overall, to optimize learning outcomes, at the beginning, game designers should prioritize building learner confidence and ensuring content relevancy to their needs. This involves implementing adjustable difficulty levels and diverse motivational strategies. Additionally, in the process of gaming, maintaining a dynamic balance between the learner's confidence and the challenge is crucial, with motivation-sustaining timely feedback as an important factor. Finally, at the post-game stage, offering positive rewards such as feedback or trophy can further encourage learners. Introducing competitive elements, where appropriate, can also stimulate interest and foster a sense of accomplishment among learners, thereby enhancing the overall educational experience.

Discussion

The study shows a clear upward trend in both publication and citations, highlighting the emerging interests in digital game-based learning within education sphere since 2020. The predominant rise of scholarly investigation concurrent with the time period of pandemic, indicating a shift of focus to digital learning studies. Since online learning has gained attention during the pandemic, digital game-based learning has also serve as a viable educational approach (Giang & Cuong, 2021). Game-based learning has been a popular topic in educational fields incorporating digital elements as traditional schooling shifted online. Extending research has been published in educational, technological contexts and so on regarding digital game-based learning (Baalsrud Hauge et al., 2022).

Challenges still existed, however, to lead the further application of digital technology in many fields. From a technical perspective, designing digital games was particularly demanding due to the required interaction among learners, game designers, and developers (Pereira de Aguiar et al., 2018). Various research related to the evaluation of the effect and impact of the application of digital games in learning has been increasingly conducted (RQ3). Diverse methods, both quantitative and qualitative, have been used to test these effects in digital game-based learning to ensure the feasibility of further studies (Huang et al., 2013; Huang et al., 2010). Various studies investigated the influence of digital games, and numerous meta-analyses revealed more positive than negative effects (Chen et al., 2018; Tsai & Tsai, 2018).

Diverse articles on digital game-based learning effects through experiments were reviewed. A teaching design model called ARCS focuses on mobilizing students' learning

motivation in four dimensions, i.e., attention, relevance, confidence and satisfaction (Keller, 1983). The model of Motivation, Volition, and Performance (MVP), proposed by W. H. Huang et al. (2010) reveals the relationship between the motivation content and the feedback. Huang et al. (2014) created the Input–Process–Outcome (IPO) model with a diagnostic mechanism prompt, highlighting the positive experience. In our research, a framework for digital game design was envisaged by combining game design and educational instruction. We aim to explore a balance between entertainment and education in game design for effective and sustainable learning. A digital game-based learning system is designed into three parts: preparation, process and settlement (PPS). The system incorporates a DGBL model with diagnostic mechanisms for sustainable learning.

The game stage and corresponding content in game design were innovatively derived from the Input–Process–Outcome (IPO) (Huang et al., 2014). The initial design of the game consists of three parts, each responsive to learners' game stages or gaming experiences. As the "i+1 principle" suggests, the challenge students face with should be slightly beyond their competence so that they can make progress (Krashen, 1982). In competition, students often exhibit strong self-regulation abilities (Yu, 2023). In the game, both intrinsic motivation and external incentives, such as satisfaction from competing with others and achieving high scores, play crucial roles (Huang et al., 2014).

Preparation reflects learners' consideration of whether they can complete tasks, which correlates with confidence and relevance. An option of adaptable difficulty is included to provide a flexible selection of difficulty of games, aiming to prevent students from feeling overwhelmed by challenges and consequently demotivated (Yu, 2023). A suitable aesthetic design may also play a role in good learner experiences. As the game progresses, diagnostic and prompt mechanism will help to retain motivation. And negative feedback mechanisms are employed to avoid a large score gap between players (Alexiou & Schippers, 2018).

In the settlement stage, learners' achievements are displayed, and suggestions for improvement are provided. Additionally, a ranking based on game scores can be introduced to offer external incentives. The diagnostic prompts could enhance adaptive learning experiences by guiding students through challenges and providing personalized feedback. Learners can adjust their strategies based on feedback, focusing on weak points and promoting their understanding of the subject matter. The competition mechanism triggers the game loop, encouraging learners to actively participate and strive for improvement to have a more profound understanding of the content. However, the competition must be balanced to avoid problems such as repetitively meaningless competition, leading learners to play for competition rather than knowledge.

The framework combined game design elements with the ACRS model, flow theory, etc., provides an auxiliary solution for promoting online teaching and learning. Within the PPS framework, diagnostic mechanisms play a crucial role in sustaining learners' engagement

and facilitating continuous learning within games. Similarly, the competitive ranking mechanisms drive the relearning cycle by motivating learners to revisit and improve their performance. By utilizing these frameworks and mechanisms, educational games can enhance learning experiences by maintaining learner engagement, adapting to individual needs through diagnostics, and encouraging continuous improvement through competition. By focusing on learners' experiences, a game designed with the PPS framework can effectively motivate learners, sustain engagement, and facilitate personalized learning. This approach contributes to the broader goal of fostering sustainable and effective online teaching and learning.

Conclusion

In our recent bibliometric analysis, we delved into the burgeoning field of digital game-based learning to uncover the key topics and domains that are driving current research and analyze its potentials to inspire further innovation. By employing VOSviewer, we identified the most influential authors, sources, organizations, and countries, pinpointing the key intellectual individuals and organization that shape this dynamic landscape. Further, we constructed a citation network, in a fashion of visual representation, to showcase the interconnectivity of the field.

Major findings

Our research reveals that the sustainability of digital learning mainly relies on several key factors: sustained motivation, effective in-game feedback, and post-game incentives. These insights are crucial for enhancing the learner's engagement and ensuring the long-term success of digital learning initiatives.

Building upon these findings, we propose a novel framework that is specifically constructed for game designers. The framework is composed of three key elements: Preparation, Process and Settlement, with each part corresponding to different stage of game. This framework aims at promoting effectiveness of digital learning by integrating motivational and instructional elements that have been proven to improve learner experience and achievement.

Limitations

While our bibliometric analysis has provided insights into digital game-based learning, several limitations must be considered when interpreting the findings. Firstly, the scope of our data was restricted to the WOS, potentially excluding other relevant but inaccessible studies. Second, the study only draws a profile of the field, which may not fully represent evolving trends in digital learning. Furthermore, our major finding: the proposed framework, and identified impact factors could vary across different educational contexts

and cultural backgrounds. Also, the framework should keep open to ongoing revisions to maintain relevant and effective. By recognizing these limitations, we encourage further research that can build upon our work, contributing to a deeper understanding of digital game-based learning and its potential in education.

Implications for future research

The potential for future research in digital game-based learning is immense. Beyond addressing the limitations noted, we propose increased collaboration between game designers and educators in the design process to ensure alignment with pedagogical principles and engaging user experiences. We envision future research that will not only apply this framework to game design but will also explore the integration of artificial intelligence. AI empowered game learning can bring personalized experiences, targeted feedback and instruction that can help learners better improve themselves (Zhu & Ontañón, 2020). By integrating the transformative potential of technology and thoughtful pedagogical design, we hope digital game-based learning could play a significant role in future education, creating an immersive, engaging and effective learning environment for all participants.

Abbreviations

GBL: Game-Based Learning; CAD: Computer-Aided Design; STEM: Science, Technology, Engineering and Mathematics; DGBL: Digital Game-Based Learning; IPO: Input–Process–Outcome; MVP: Motivation, Volition, and Performance; ARCS: Attention, Relevance, Confidence and Satisfaction; PPS: Preparation, Process and Settlement; WOS: Web of Science; DGBLL: Digital Game-Based Language Learning; ESL: English as a Second Language; MMORPGs: Multiplayer Online Role-Playing Games.

Acknowledgements

This work is supported by research project of Beijing Language and Culture University “Innovative Approaches to Digital Material Integration and Utilization in Postgraduate Education” (Project No.: SJJG202301), Beijing Higher Education Undergraduate Teaching Reform and Innovation Project “Personalized English Teaching Based on the Intelligent Teaching Platform” (2023).

Authors’ contributions

Panlong Wang is responsible for investigation, writing the original draft, editing. Han Yi contributes to conceptualization, methodology, proofreading, revision and funding. All authors read and approved the final manuscript.

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Funding

This work is supported by research project of Beijing Language and Culture University “Innovative Approaches to Digital Material Integration and Utilization in Postgraduate Education” (Project No.: SJJG202301), Beijing Higher

Education Undergraduate Teaching Reform and Innovation Project "Personalized English Teaching Based on the Intelligent Teaching Platform" (2023).

Availability of data and materials
Not applicable.

Declarations

Competing interests
The authors declare that they have no conflicts of interest to declare that are relevant to the content of this article.

Received: 18 December 2023 Accepted: 20 August 2024
Published online: 7 January 2025

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