Trends of Game-Based Learning in the Mobile Era: A Review of the Top 100 Highly Cited Empirical Studies

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Abstract

Highly cited papers reflect current research trends and important issues. By reviewing such papers, researchers can efficiently identify key topics in their field. To explore trends in game-based learning, this study reviewed the top 100 highly cited papers in the field. Seven key insights were found: (1) trends in blended learning research methods; (2) the most common game types used in game-based learning research; (3) development of game types in game-based learning; (4) the most used experimental devices; (5) participant types; (6) positive or negative results of learning; and (7) various types of teaching support, such as models and feedback, which have been proven to be more effective than other methods. Some studies prioritized comparing game-based learning models to find more effective methods, rather than contrasting them with traditional instruction. Others focused on learners' performance and feedback. This research also provides new suggestions for future studies.

Keywords: Game-based learning, Highly cited papers, Web of Science, Social Sciences Citation Index, Research trends

1 Introduction

In the mobile era, game-based learning has been recognized as an effective approach that enhances students' engagement and participation. Its purpose is to improve learning outcomes by embedding educational elements into gameplay [1]. Squire [2] emphasized that computer games can construct vivid virtual environments that make complex problems interesting and stimulate learning. Kinzie and Joseph [3] noted that games encourage active participation through challenging goals. Empirical studies further showed that game-based learning enhances achievement [4], motivation [5], and enjoyment [6], ultimately improving performance [7]. Hsieh et al. [8] found that it fosters flow experiences and learning performance, while Sun et al. [9] demonstrated its effectiveness in improving anti-phishing knowledge. Similarly, Shi et al. [10] reported that VR games significantly increased students' motivation and achievement in mathematics.

In addition to empirical evidence, several review studies have examined research trends in game-based learning. Hwang and Wu [11] analyzed journal publications from 2001 to 2010 and reported a rapid growth of related studies. Connolly et al. [12] reviewed 129 papers and confirmed positive effects on young learners. Hung et al. [13] reviewed 50 empirical studies from 2007 to 2016 and concluded that digital games support language and literacy learning among both native and non-native speakers.

While many retrospective studies exist, they often focus on limited timeframes. Lai [14] stressed the importance of identifying long-term research trends by analyzing highly cited articles, which reflect essential issues in the field. Previous works in other domains also analyzed highly cited studies to highlight key directions [15]. For example, Kinshuk et al. [16] reviewed influential publications in Educational Technology and Society, noting the rise of game-based learning as an academic focus. Cheng et al. [17] argued that highly cited educational research often features effective models, robust theories, and widely adopted statistical methods, which can guide high-quality research designs.

However, few studies have explored research trends in game-based learning through highly cited empirical articles. To address this gap, this study examined the top 100 highly cited SSCI-indexed empirical studies on game-based learning. The following research questions were formulated:

RQ1: What research designs and purposes are adopted in the top 100 highly cited articles?

RQ2: What learning devices, game features, game types, and collaborative methods are used?

RQ3: What statistical analyses and measurement approaches are applied?

RQ4: Who are the top 10 most productive authors in this field?

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2 Literature Review

Game-based learning (GBL) is a method that enables learners to construct knowledge through game content, connect prior knowledge to solve problems, and enhance performance [18]. Numerous studies confirm that GBL effectively activates motivation [19-20] and has been applied across mathematics [21], language [22], science [23], and environmental education [24].

Recent research has increasingly examined GBL trends by analyzing publications, focusing on authorship, journals, keywords, participants, learning devices, and assessment methods. Al-Emran et al. [25] highlighted that such reviews provide comprehensive insights and useful implications. Wouters and van Oostendorp [26], through meta-analysis (1990–2012), showed that instructional support in GBL facilitates skill acquisition and effective information selection, recommending emphasis on learning content over visual design.

Table 1 summarizes coding schemes and findings from prior reviews. Most studies employed quantitative designs, with some adopting qualitative approaches, particularly in higher education. Participants were often elementary or college students, and learning contexts varied. Frequently discussed outcomes included achievement, motivation, attitudes, knowledge acquisition, and affective states, with personal computers and mobile devices being the most common platforms.

Although research trend studies are increasing, few have analyzed highly cited GBL articles. Such papers represent classical and influential works that highlight key issues and directions in the field [27]. They reveal what topics attract sustained scholarly attention and provide valuable references for future research.

Table 1. The coding scheme and frequency of application in previous game-based learning review studies

Authors	Published journals	Review duration	Number of papers	Frequent research designs	Frequent devices used	Frequent application domains	Frequent participants	Frequent statistical methods	Frequent measurement issues
Chang and Hwang (2019)	Int. J. Mobile Learning and Organization	2007-2016	113	Mixed methods/ Quantitative analysis/ Quantitative analysis	Smartphone /tablet/ computers	Engineering/ computers/ Health/ social studies	Elementary school/ High school/ Higher education students	Descriptive analysis / t-test/ ANCOVA/ correlation	Learning achievement/ Motivation/ Attitude
Hung, Yang, Hwang, Chu and Wang (2018)	Computers & Education	2007-2016	47	Mixed methods/ Quantitative analysis/ Quantitative analysis	Smartphone /tablet/ computers	Engineering/ computers / science/	Elementary school/ High school/ Higher education students	Descriptive analysis / t-test/ ANCOVA/ correlation	Learning performance/ motivation/ interaction/
Wouters and Van Oostendorp (2013)	Computers & Education	1990-2012	29	Experimental design/ Quantitative analysis/ Quantitative analysis	Smartphone /tablet/ computers	Engineering/ computers / science/ social studies	High school/ Higher education students		Learning achievement/ motivation/
Li and Tsai (2013)	Journal of Science Education and Technology	2000-2011	31	Experimental design/ Quantitative analysis	Smartphone / computers	Science education	Elementary school students	Descriptive analysis / t-test/ ANCOVA	Learning achievement/ affective learning
Hwang and Wu (2012)	British Journal of Educational Technology	2001-2010	137	Experimental design/ Quantitative analysis	tablet/ computers	Engineering/ computers / social science/ math/ language	Elementary school/ High school/ Higher education students		Learning achievement/ motivation/ attitudes

3 Research Methods

3.1 Resources

The Web of Science database (WoS) was targeted on the basis of its reliability and authority. The Boolean expressions ("game" OR "gaming") AND ("learning" OR "education" OR "teaching" OR "instruction") were used to search for the topics of SSCI publications in the WoS database from 1999 to 2025 based on previous studies [27]. As a result, an initial total of 18,631 papers were found on July 26th, 2025. The category was then limited to education and educational research, and the literature type was limited to "article" based on the suggestions of several previous studies [27]. In total, 3,991 papers were analyzed. These papers were sorted by citation count from highest to lowest, and the top 100 articles featuring experimental design were selected. The search procedure in the WoS database is illustrated in Figure 1.

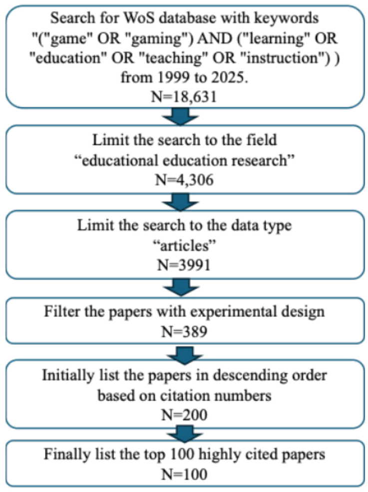

Figure 1. Searching procedure of the WoS database

Figure 2. The publication situation of the published game-based learning papers published from 1991 to 2025

3.2 Data Distribution

Figure 3 presents the distribution of the top 100 highly cited game-based learning (GBL) papers from 1991 to 2025. The earliest influential work appeared in 2007, when Squire and Klopfer [28] developed Environmental Detectives, an augmented reality simulation game that enhanced students' understanding of science through real-world inquiry.

After 2013, publications grew rapidly, reflecting the adoption of GBL across multiple subjects, as shown in Figure 2. This trend indicates a growing academic interest and momentum surrounding game-based learning over the past decade. For example, Hwang et al. [29] showed that online board games could foster problem-solving and engagement. Wang [30] found that Kahoot! sustained motivation despite slight wear-out effects, and Hew et al. [31] demonstrated that game elements such as points and leaderboards increased engagement, though not necessarily recall. Habgood and Ainsworth [32] further explored intrinsic motivation, while Sung and Hwang [23] integrated collaborative Mindtools into GBL, improving achievement and self-efficacy. Hwang et al. [33] integrated a peer assessment approach into game-based learning scenarios, which enhanced motivation and problem-solving skills.

Overall, research attention has gradually shifted from confirming the effectiveness of GBL toward integrating new approaches (e.g., collaboration, peer assessment) and examining broader outcomes such as self-efficacy, attitudes, and learning behavior.

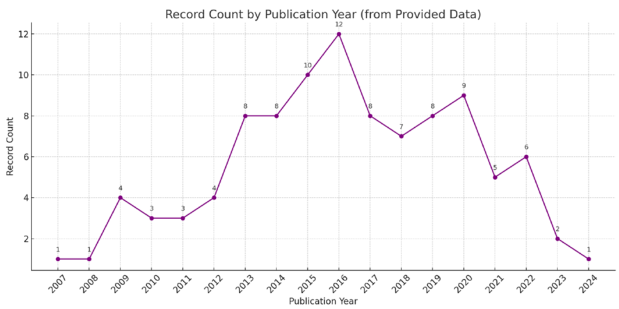

Figure 3. Distribution status of highly cited game-based learning research

As Figure 3 shows, studies published after 2021 have yet to accumulate significant citations; thus, our analysis emphasizes highly cited works up to 2020. These publications collectively highlight the evolution of GBL research from effectiveness studies toward more nuanced explorations of pedagogy and learner experience.

3.3 Coding Schemes

To analyze the highly cited game-based learning (GBL) studies, this research adopted the Technology-based Learning Model (TLM) [14, 18, 34], which emphasizes three key factors: learners, technologies, and environments (Figure 4). The intersections among these factors generate research issues (environments × technologies), interaction issues (learners × technologies), and performance issues (environments × learners).

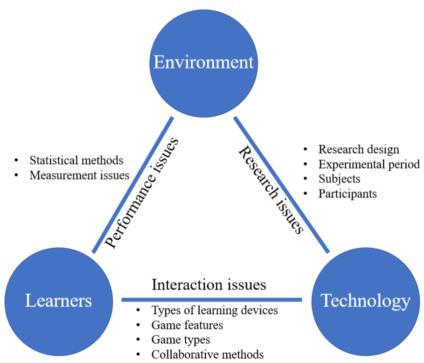

Figure 4. Technology-based learning model for game-based learning

Accordingly, this study categorized research dimensions as follows:

- Research issues: research designs, experimental duration, subjects, and participants.
- Interaction issues: learning devices, game features, game types, and collaborative methods.
- Performance issues: statistical methods and measurement indicators (e.g., achievement, motivation).

(Table 2 presents the coding scheme.)

Table 2. The coding scheme for analyzing the highly cited game-based learning research

Categories	Description	Aspects	Description or Example
1. Research designs	The method used to collect and analyze data for answering the research questions with reference to McMillan and Schumacher (2006), Lai (2020)	Experimental design	Pre-, quasi-, or true experimental design research
		Quantitative design	Descriptive or survey studies
		Qualitative design	Interview, observation or content analysis research
		Mixed methods	Employed at least 2 research designs mentioned above
2. Experimental duration	The experimental duration lasts from the beginning of the pre-test to the end of the post-test with reference to Hung, Yang, Hwang, Chu and Wang (2018)	One lesson	Only one lesson to carry out the experiment
		Short-term lessons	Up to 10 weeks
		Mid-term lessons	From11 weeks to 4 months
		Long-term lessons	More than 4 months
3. Types of learning devices	Learning activities via specific technology with reference to Ozdamli and Uzunboylu's (2015) study	Tablet PCs	
		Computers	Desktops
		Traditional mobile devices	Laptops, PDAs
		Smart phones	Mobile phones
		Wearable devices	3D virtual head-mounted VR
		Mixed / varied or not - specified	Employed two or more types of devices mentioned above.
		No use any devices	No specific learning device
4. Game features	With reference to Boyle et al., (2016), Hung, Yang, Hwang, Chu and Wang (2018)	Three features of games are included: accessibility, mobility and Interactivity.	
		No activities	
5. Playing games or Making games	Participants are involved in learning by playing or making games with reference to Li and Tsai (2013)	Playing games	Participants take part in learning activities via playing games.
		Making games	Participants take part in learning activities via making games.
6. Game types	Based on the number of players in a game with reference to Li and Tsai (2013).	Single player	Only one player allowed to play the game.
		Multiple players	Several players allowed to play the game.
		Massively multiplayer online	It is a large-scale multiplayer online game.
		Multiplayer classroom game	Through a host, multiple players are allowed to achieve multi-role play simultaneously in online games in the classroom.
		Mixed game	Online game contains two or more game types.
		other	Other types.
7. Subjects	Subjects are taught in the experiment of study with reference to Lin and Hwang (2018).	10 subjects are included: science, mathematics, art, language, social study, engineering, medical care, business, cross-interdisciplinary, and mixed.	
8. Statistical methods	Statistical methods used in analyzing data collection with reference to Lai (2020).	13 aspects: descriptive, chi-square, *t* tests, one-way ANOVA/ANCOVA, two-way ANOVA/ANCOVA, principal components analysis, regression analysis, structure equation model (SEM), cluster analysis, time series, sequential pattern analysis, interviews or none.	

In addition, authors' productivity was included as a reference for identifying influential contributors, which is valuable for novice scholars [35]. To quantify contributions in multi-authored papers, the formula of Howard et al. [36] was adopted. This approach considers both the number of authors (n) and the order of authorship (i), allowing weighted attribution of citations. For example, in Hwang, Chu, and Lai [37], if the study received 100 citations, the authors' scores were calculated as 47, 32, and 21, respectively.

4 Research Results

4.1 Analysis of Research Issues

Table 3 shows the distribution of research designs in GBL studies. Mixed methods were relatively common in the first period (17%), but quantitative methods later dominated, constituting 51% overall, while mixed methods and qualitative designs accounted for 34% and 15%. This indicates a preference for quantitative approaches, with mixed methods gradually increasing in later years.

Table 3. Percentage of research designs in each period

Period	I	II	III	**I-III**
Research Designs	1999-2008 (N=19)	2009-2013 (N=66)	2014-2020 (N=15)	**1999-2020 (N=100)**
Quantitative	21%(N=4)	56%(N=37)	67%(N=10)	**51%(N=51)**
Qualitative	32%(N=6)	14%(N = 9)	0%(N=0)	**15%(N=15)**
Mixed Methods	47%(N=9)	30%(N=20)	33%(N = 5)	**34%(N=34)**

Regarding experimental duration (Table 4), early studies often used single or short lessons (42% and 26%). In later periods, short-term designs became dominant (44% and 60%), suggesting they were most effective in sustaining students' cognition and motivation [38]. Mid- and long-term designs were less effective; for instance, Ebner and Holzinger [39] reported no significant differences in a three-month quasi-experiment, implying reduced attention and diminished GBL effects over longer spans.

Table 4. Percentage of experimental duration in each period

Period	I	II	III	**I-III**
Experimental duration	1999-2008 (N=19)	2009-2013 (N=66)	2014-2020 (N=15)	**2000-2016 (N=100)**
One lesson	42%(N=8)	30%(N=20)	27%(N=4)	**32%(N=32)**
Short-term lessons (up to 10 weeks)	26%(N=5)	44%(N=29)	60%(N=9)	**43%(N=43)**
Mid-term lessons (11 weeks to 4 months)	11%(N=2)	9%(N=6)	0%(N=0)	**8%(N=8)**
Long-term lessons (more than 4 months)	21%(N=4)	17%(N=11)	13%(N=2)	**17%(N=17)**

In terms of application domains (Table 5), science courses were most prevalent (26%), followed by language (15%), engineering/computers (12%), and mathematics (10%). Social sciences (7%), mixed courses (5%), and other fields (16%) were less common, while arts had none. Representative examples include Hwang, Wu, and Chen [29], who used online board games to improve elementary students' science problem-solving. In higher education, Cagiltay et al. [40] showed that competitive mechanisms in serious games improved motivation and performance more than non-competitive versions.

Table 5. Percentage of application domains in each period

Period	I	II	III	**I-III**
Application domains	1999-2008 (N=19)	2009-2013 (N=66)	2014-2020 (N=15)	**1999-2020 (N=100)**
Science	21%(N=4)	24%(N=16)	40%(N=6)	**26%(N=26)**
Mathematics	11%(N=2)	12%(N=8)	0%(N=0)	**10%(N=10)**
Arts or design	0%(N=0)	0%(N=0)	0%(N=0)	**0%(N=0)**
Languages	5%(N=1)	17%(N=11)	20%(N=3)	**15%(N=15)**
Social science or social studies	0%(N=0)	9%(N=6)	7%(N=1)	**7%(N=7)**
Engineering or computers	11%(N=2)	11%(N=7)	20%(N=3)	**12%(N=12)**
Health, Medical or Nursing	0%(N=0)	5%(N=3)	0%(N=0)	**3%(N=3)**
Business and management	5%(N=1)	3%(N=2)	0%(N=0)	**3%(N=3)**
Interdisciplinary	0%(N=0)	5%(N=3)	0%(N=0)	**3%(N=3)**
Mixed course	5%(N=1)	6%(N=4)	0%(N=0)	**5%(N=5)**
Other	42%(N=8)	9%(N=6)	13%(N=2)	**16%(N=16)**

Participant analysis (Table 6) shows that most studies targeted elementary (35%) and higher education (27%) students, followed by junior high (16%), mixed groups (15%), and senior high (4%). Few focused on teachers or adults. Notably, elementary students became the largest group in the third period (47%). Examples include Guillén-Nieto and Aleson-Carbonell [41], whose simulation game improved intercultural communication in Business English, and Barzilai and Blau [42], whose scaffolding strategies significantly enhanced young learners' problem-solving outcomes.

Table 6. Percentage of participants in each period

Period	I	II	III	**I-III**
Participants	1999-2008 (N=19)	2009-2013 (N=66)	2014-2020 (N=15)	**1999-2020 (N=100)**
Elementary school students	37%(N=7)	32%(N=21)	47%(N=7)	**35%(N=35)**
Junior high school students	5%(N=1)	17%(N=11)	27%(N=4)	**16%(N=16)**
Senior high school students	0%(N=0)	6%(N=4)	0%(N=0)	**4%(N=4)**
Higher education students	42%(N=8)	24%(N=16)	20%(N=3)	**27%(N=27)**
Teachers	0%(N=0)	0%(N=0)	0%(N=0)	**0%(N=0)**
Working adults	0%(N=0)	0%(N=0)	0%(N=0)	**0%(N=0)**
Mixed group	11%(N=2)	18%(N=12)	7%(N=1)	**15%(N=15)**
No clear description	0%(N=0)	0%(N=0)	0%(N=0)	**0%(N=0)**
No participants	0%(N=0)	0%(N=0)	0%(N=0)	**0%(N=0)**
Other	5%(N=1)	3%(N=2)	0%(N=0)	**3%(N=3)**

Overall, research designs have shifted toward short-term, quantitative studies applied primarily in science and language domains, with elementary and higher education students as the main participants.

4.2 Analysis of Interaction Issues

Table 7 shows that most GBL studies relied on traditional computers (75%), with smaller shares for smartphones (6%), mobile devices (5%), and tablets (3%). In the third period, smartphones emerged as the second most used device, reflecting the gradual acceptance of BYOD (Bring Your Own Devices).

Table 7. Percentage of learning devices in each period

Period	I	II	III	**I-III**
Learning devices	1999-2008 (N=19)	2009-2013 (N=66)	2014-2020 (N=15)	**1999-2020 (N=100)**
Computers	74%(N=14)	76%(N=50)	73%(N=11)	**75%(N=75)**
Tablet PCs	0%(N=0)	5%(N=3)	0%(N=0)	**3%(N=3)**
Traditional mobile devices (PDA)	16%(N=3)	3%(N=2)	0%(N=0)	**5%(N=5)**
Smart phones	0%(N=0)	5%(N=3)	20%(N=3)	**6%(N=6)**
Wearable devices	0%(N=0)	0%(N=0)	0%(N=0)	**0%(N=0)**
Mixed / varied devices	0%(N=0)	3%(N=2)	0%(N=0)	**2%(N=2)**
Not-specified	11%(N=2)	0%(N=0)	7%(N=1)	**3%(N=3)**
No use of devices	0%(N=0)	2%(N=1)	0%(N=0)	**1%(N=1)**
Others	0%(N=0)	8%(N=5)	0%(N=0)	**5%(N=5)**

Regarding game features (Table 8), self-developed games dominated (44%), followed by free or mixed games (14%). Computer/online games accounted for 69% overall, indicating their central role in GBL. In terms of interactivity, simulation games (35%) and role-playing games (20%) were the most common, with role-playing increasing to 33% in the third period. Educational games accounted for 13%. Representative studies include Chen and Tsai [43], who found AR library games improved achievement, though effects varied by learning style.

Table 8. Percentage of game features in each period

Period		I	II	III	**I-III**
Game features	Dimensions	1999-2008 (N=19)	2009-2013 (N=66)	2014-2020 (N=15)	**1999-2020 (N=100)**
Accessibility	Paid games	5%(N=1)	14%(N=9)	13%(N=2)	**12%(N=12)**
	Free games	16%(N=3)	9%(N=6)	33%(N=5)	**14%(N=14)**
	Self-developed games	37%(N=7)	47%(N=31)	40%(N=6)	**44%(N=44)**
	Not clearly stated	21%(N=4)	18%(N=12)	0%(N=0)	**16%(N=16)**
Mobility	Mixed / varied	21%(N=4)	12%(N=8)	13%(N=2)	**14%(N=14)**
	Video games	0%(N=0)	14%(N=9)	0%(N=0)	9%(N=9)
	Computer games/ Online games	68%(N=13)	67%(N=44)	80%(N=12)	**69%(N=69)**
	Mobile games	16%(N=3)	15%(N=10)	20%(N=3)	**16%(N=16)**
	Not clearly stated	11%(N=2)	3%(N=2)	0%(N=0)	4%(N=4)
Interactivity	Mixed / varied	5%(N=1)	2%(N=1)	0%(N=0)	2%(N=2)
	Simulation games	37%(N=10)	37%(N=30)	28%(N=5)	**35%(N=45)**
	Role-playing games	15%(N=4)	18%(N=15)	33%(N=6)	**20%(N=25)**
	Educational games	7%(N=2)	13%(N=11)	17%(N=3)	**13%(N=16)**
	Escape games	4%(N=1)	4%(N=3)	0%(N=0)	3%(N=4)
	Motion-Sensing games	0%(N=0)	1%(N=1)	0%(N=0)	1%(N=1)
	Board games	0%(N=0)	1%(N=1)	0%(N=0)	1%(N=1)
	Mobile games	0%(N=0)	2%(N=2)	0%(N=0)	2%(N=2)
	Augmented Reality	4%(N=1)	1%(N=1)	6%(N=1)	2%(N=3)
	Virtual Reality	4%(N=1)	2%(N=2)	0%(N=0)	2%(N=3)
	Mixed / varied	22%(N=6)	15%(N=12)	6%(N=1)	**15%(N=19)**
	Others	7%(N=2)	5%(N=4)	11%(N=2)	6%(N=8)

Table 9 indicates that "playing games" overwhelmingly dominated (92%), while "making games" represented only 8%. Although less common, game-making was shown to foster motivation and reflection. For example, Ke [44] reported that elementary students making math games demonstrated higher confidence and engagement.

Table 9. Percentage of playing or making games in each period

Period	I	II	III	I-III
Playing or making games	1999-2008 (N=19)	2009-2013 (N=66)	2014-2020 (N=15)	**1999-2020 (N=100)**
Playing games	89%(N=17)	94%(N=62)	87%(N=13)	**92%(N=92)**
Making games	11%(N=2)	6%(N=4)	13%(N=2)	**8%(N=8)**

In terms of game types (Table 10), single-player games were most prevalent (72%), reaching 80% in the third period, reflecting both design simplicity and lower costs. Multiplayer and massively multiplayer formats accounted for less than 10% each, though mixed formats (e.g., Kebritchi et al. [21]) showed potential for mathematics learning.

Table 10. Percentage of game types in each period

Period	I	II	III	I-III
Game types	1999-2008 (N=19)	2009-2013 (N=66)	2014-2020 (N=15)	**1999-2020 (N=100)**
Single player	63%(N=12)	72%(N=47)	80%(N=12)	**72%(N=71)**
Multiple players	11%(N=2)	12%(N=8)	0%(N=0)	**10%(N=10)**
Massively multiplayer online	5%(N=1)	8%(N=5)	13%(N=2)	**8%(N=8)**
Multiplayer classroom game	0%(N=0)	3%(N=2)	7%(N=1)	**3%(N=3)**
Mixed game	16%(N=3)	5%(N=3)	0%(N=0)	**6%(N=6)**
Other	5%(N=1)	0%(N=0)	0%(N=0)	**1%(N=1)**

Collaboration patterns (Table 11) revealed that 71% of studies involved no collaboration, 21% used real-world collaboration, and 8% used virtual collaboration. The predominance of individual-focused GBL reflects design challenges and measurement simplicity. When collaboration was included, researchers favored real-world interactions over virtual ones. For instance, Bressler and Bodzin [45] integrated AR into middle school science, where students collaborated on campus-based problem-solving via mobile devices.

Table 11. Percentage of collaborative methods in each period

Period	I	II	III	I-III
Collaborative methods	1999-2008 (N=19)	2009-2013 (N=66)	2014-2020 (N=15)	**1999-2020 (N=100)**
Real-world collaboration	21%(N=4)	23%(N=15)	13%(N=2)	**21%(N=21)**
Virtual-world collaboration	11%(N=2)	9%(N=6)	0%(N=0)	**8%(N=8)**
No collaboration	68%(N=13)	68%(N=44)	87%(N=13)	**71%(N=70)**

In summary, interaction-focused studies indicate that computers and online games remain dominant platforms; most games were self-developed, simulation or role-playing in type, and played individually. While collaborative and game-making approaches are less common, they demonstrate potential for enhancing motivation, reflection, and problem-solving.

4.3 Analysis of Performance Issues

Table 12 shows the distribution of statistical methods. The most frequently used were descriptive statistics (25%), *t*-tests (14%), interviews (14%), and one-way ANOVA/ANCOVA (12%). Less common were chi-square (5%), two-way ANOVA/ANCOVA (4%), regression (4%), and advanced analyses such as principal components or sequential pattern analysis (1%). Structural equation modeling (SEM) and cluster analysis were rarely applied. Overall, these findings indicate that most highly cited GBL studies relied on basic quantitative analyses, with t-tests increasingly used in later years. Interviews, which constituted nearly 30% in the first period, declined to about 12%, reflecting a shift toward quantitative approaches consistent with earlier findings on research design.

Table 12. Percentage of statistical methods in each period

Period	I	II	III	I-III
Statistical methods	1999-2008 (N=19)	2009-2013 (N=66)	2014-2020 (N=15)	**1999-2020 (N=100)**
Descriptive	33%(N=13)	25%(N=47)	17%(N=8)	**25%(N=68)**
Chi-square	5%(N=2)	6%(N=11)	4%(N=2)	**5%(N=15)**
t tests	13%(N=5)	13%(N=24)	21%(N=10)	**14%(N=39)**
One-way ANOVA/ANCOVA	8%(N=3)	14%(N=25)	10%(N=5)	**12%(N=33)**
Two-way ANOVA/ANCOVA and advanced	0%(N=0)	5%(N=10)	10%(N=5)	**5%(N=15)**
Principal components analysis	0%(N=0)	2%(N=3)	0%(N=0)	**1%(N=3)**
Regression analysis	0%(N=0)	5%(N=9)	4%(N=2)	**4%(N=11)**
SEM	0%(N=0)	0%(N=0)	2%(N=1)	**0%(N=1)**
Cluster analysis	0%(N=0)	1%(N=1)	0%(N=0)	**0%(N=1)**
Time series	0%(N=0)	0%(N=0)	0%(N=0)	**0%(N=0)**
Sequential pattern analysis	0%(N=0)	2%(N=3)	2%(N=1)	**1%(N=4)**
Interview	28%(N=11)	12%(N=22)	13%(N=6)	**14%(N=39)**
Other	15%(N=7)	16%(N=29)	17%(N=8)	**16%(N=43)**
None	0%(N=0)	1%(N=1)	0%(N=0)	**0%(N=1)**

Table 13 presents measurement issues categorized into cognition, affect, technical, behavioral, and correlation. Cognitive achievement was the most studied outcome (23%), while higher-order thinking (5%) and collaboration/communication (2%) were seldom examined. In the affective dimension, learning motivation (13%), satisfaction/interest (9%), and technology acceptance (5%) were common, but interviews/open-ended questions, initially 20%, declined sharply over time. Self-efficacy (2%) and cognitive load (1%) were less frequently addressed. Technical skill learning (3%) and behavioral performance (3%) also appeared in a minority of studies. Correlation analysis accounted for 9%, focusing on cause–and–effect relationships.

Table 13. Percentage of measurement issues in each period

Period		I	II	III	I-III
Dimension	Sub-dimension	1999-2008 (N=19)	2009-2013 (N=66)	2014-2020 (N=15)	**1999-2020 (N=100)**
	Achievement	21%(N=8)	24%(N=37)	22%(N=11)	**23%(N=56)**
Cognition	Higher-order thinking performance	5%(N=2)	6%(N=10)	2%(N=1)	**5%(N=13)**
	Collaboration/ Communication	3%(N=1)	2%(N=3)	0%(N=0)	**2%(N=4)**
	Technology acceptance	8%(N=3)	4%(N=6)	4%(N=2)	**5%(N=11)**
	Attitude/ Effort	5%(N=2)	5%(N=7)	6%(N=3)	**5%(N=12)**
	Motivation	10%(N=4)	13%(N=20)	16%(N=8)	**13%(N=32)**
Affect	Self-efficacy/ Belief	0%(N=0)	2%(N=3)	6%(N=3)	**2%(N=6)**
	Satisfaction/ Interest	3%(N=1)	9%(N=14)	14%(N=7)	**9%(N=22)**
	Cognitive load	0%(N=0)	1%(N=2)	0%(N=0)	**1%(N=2)**
	Interview or open-ended questions	41%(N=16)	17%(N=26)	12%(N=6)	**20%(N=48)**
Technical	Learning performance (skillful)	0%(N=0)	4%(N=6)	4%(N=2)	**3%(N=8)**
Behavioral	Behavioral analysis	0%(N=0)	3%(N=5)	6%(N=3)	**3%(N=8)**
Correlation	Correlation or Cause-and-effect Analysis	5%(N=2)	10%(N=16)	8%(N=4)	**9%(N=22)**

Across the three periods, attention to motivation and satisfaction increased, while reliance on interviews decreased, again consistent with the general trend toward quantitative designs. Learning achievement remained a central focus throughout, exceeding 20% in all periods. These results suggest that researchers increasingly prioritized motivation and affective engagement, alongside achievement, as key indicators of GBL effectiveness, while qualitative measures became secondary.

4.4 Published Papers by Authors' Productivity

Table 14 lists the top 10 authors based on productivity scores. In the first period (1999–2008), most were from

English-speaking countries (e.g., UK, USA, Australia). During 2009–2013, contributions expanded to include Asia (notably Taiwan). In the last period (2014–2022), authors came from a broader range including the USA, Canada, Taiwan, Germany, and Spain.

Table 14. Comparisons of author productivity scores in 1999–2022 (top 10)

	1999-2008		2009-2013		2014-2020		**All**	
	Author	Score	Author	Score	Author	Score	**Author**	**Score**
1.	Ke, F. (USA)	31	Papasterg iou, M. (Greece)	61 7	Hwang, G. J. (Taiwan)	118.13	**Papastergiou, M. (Greece)**	**617**
2.	Ebner, M. (Austria)	18 .8	Hwang, G. J. (Taiwan)	25 4.65	Ke, F. (USA)	92	**Ke, F. (USA)**	**406**
3.	Virvou, M (Greece)	15 .13	Sung, H. Y. (Taiwan)	14 3.24	Su, C. H. (Taiwan)	73.8	**Hwang, G. J. (Taiwan)**	**372.78**
4.	Kiili, K. (Finland)	13	Yang, Y. T. C. (Taiwan)	14 1.4	Filsecker, M. (Germany)	60.6	**Ebner, M. (Austria)**	**184.8**
5.	Holzinger, A. (Austria)	12 .2	Liu, T. Y. (Taiwan)	13 6.8	Barzilai, S. (Israel)	54.6	**Virvou, M (Greece)**	**157.13**
6.	Robertson, (UK)	10 .2	Falloon, G. (New Zealand)	12 9	Cheng, C. H. (Taiwan)	49.2	**Sung, H. Y. (Taiwan)**	**143.24**
7.	Katsionis, ((Greece)	10 .08	Annetta, L. A. (USA)	11 6.76	Hickey, D. T. (USA)	40.4	**Yang, Y. T. C. (Taiwan)**	**141.4**
8.	Squire, K. (USA)	10 .6	Habgood, M. P. J. (UK)	11 5.8	Luis, d. M. (Spain)	36.66	**Kiili, K. (Finland)**	**137**
9.	Amory, A (South Africa)	82 74	Kebritchi , M. (USA)	11 4.68	Ina B. (Israel)	36.4	**Liu, T. Y. (Taiwan)**	**136.8**
10.	Ranalli, J. (USA)	79	Fu, F. L. (Taiwan)	10 6.69	Reinders, H. (New Zealand)	31.8	**Annetta, L. A. (USA)**	**129.15**

Overall, Papastergiou, M. (Greece) was the most productive, followed by Ke, F. (USA), Hwang, G. J. (Taiwan), Ebner, M. (Austria), Virvou, M. (Greece), Sung, H. Y. (Taiwan), Yang, Y. T. C. (Taiwan), Kiili, K. (Finland), Liu, T. Y. (Taiwan), and Annetta, L. A. (USA). Nationality statistics (Table 15) show four authors from Taiwan, two each from the USA and Greece, and one each from Austria and Finland, highlighting Taiwan's strong presence in this field.

Trends in methodology also aligned with geographic shifts: early works from English-speaking countries often applied mixed methods, while later studies, particularly from Asia, emphasized quantitative approaches. Likewise, statistical techniques evolved from descriptive analysis and interviews toward t-tests, ANOVA/ANCOVA, and more advanced methods, reflecting increasing methodological rigor among the most productive scholars.

Table 15. Comparisons of Nationality statistics of highly cited authors in 1999–2022 (top 10)

1999-2008		2009-2013		2014-2020		**1999-2020**	
USA	3	Taiwan	5	Taiwan	3	**Taiwan**	**4**
Australia	2	USA	2	USA	2	**USA**	**2**
Greece	2	UK	1	Israel	2	**Greece**	**2**
Finland	1	Greece	1	Germany	1	**Australia**	**1**
UK	1	Finland	1	Spain	1	**Finland**	**1**
South Africa	1			New Zealand	1		

5 Conclusions

Highly cited papers have been regarded as representing useful and high-quality indicators for follow-up research [46]. This study reviewed the top 100 most cited game-based learning (GBL) studies (1999–2022) to propose future research directions, based on the technology-based learning model (TLM) of environment, learners, and technology.

To address research issues (RQ1) regarding the research issues, the top 100 highly cited empirical studies of game-based learning research tended to be quantitative research, and were mainly aimed at elementary school students and higher education. The experiment duration was usually short-term (one lesson to 10 weeks) to test the impact of the game-based learning approach on science courses. To answer research issues (RQ2) on the interaction issue of game design, most of the experimental devices tended to be traditional desktop computers, and the researchers developed games on their own. Learners usually played simulation games or role-playing games in single-player mode rather than collaboratively. In response to research issues (RQ3), most researchers adopted descriptive analysis, t-tests, one-way ANOVA/ANCOVA, and interviews as the statistical methods. Learning achievement, learning motivation, satisfaction, or interest in game-based learning research were the main measurement issues in the past two decades. In response to research issues (RQ4) concerning the authors' paper productivity, among the top 100 highly cited empirical studies of game-based learning, the top 10 most productive authors are Papastergiou, M. (Greece), Ke, F. (USA), Hwang, G. J. (Taiwan), Ebner, M. (Austria), Virvou, M. (Greece), Sung, H. Y. (Taiwan), Yang, Y. T. C. (Taiwan), Kiili, K. (Finland), Liu, T. Y. (Taiwan), and Annetta, L. A. (USA) when ranked by the number of citations.

These findings align with prior reviews. For example, Hung et al. [13] indicated: (1) most of the game-based learning research published early adopted mixed methods as the research method; (2) most research adopted self-developed games in the experiments by researchers; (3) the most frequently used experimental devices were traditional computers; (4) higher education participants were chosen as the experimental targets; (5) positive results were consistent with Wouters et al.'s findings [26], showing that various types of learning strategies, such as learning models and feedback should be added. It would be more effective for students to combine learning models with the game-based learning approach, rather than using game-based learning intervention alone.

There are some limitations to the present study that should be noted. First, this review focused primarily on highly cited game-based learning articles and conducted analysis based on the technology-based model; therefore, some results might not be highlighted in this analysis. Second, in the educational technology field, researchers generally determine authors' productivity through their sequences in one study [36, 47]. Therefore, it is suggested that, in future research, analysis of authors' productivity, such as the equal contribution norm, the percent-contribution-indicated approach, h-index, and Google Scholar citations, can be included further to conduct a comprehensive discussion [48]. Moreover, it is suggested that the highly cited papers and more advanced studies can be included to conduct a large-scale and comprehensive review.

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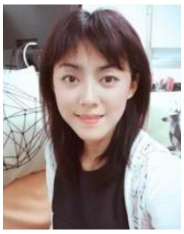
Biographies



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