Bulletin of Electrical Engineering and Informatics
Vol. 15, No. 2, April 2026, pp. 1803~1820
ISSN: 2302-9285, DOI: 10.11591/eei.v15i2.10629

Gamified learning in virtual reality: a scoping review (2010-2025)

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Article Info

Article history:

Received May 10, 2025
Revised Mar 4, 2026
Accepted Mar 10, 2026

Keywords:

Big data
Cloud computing
Educational games
Gamification
Virtual reality
Virtual reality development strategies

ABSTRACT

This paper provides a scoping review of gamified learning in virtual reality (VR) from 2010-2025, which combines trends from various disciplines, game types, and learning approaches. This paper differs from previous ones, which mainly focus on bibliometric results, by critically examining 108 publications to determine the dominant types of VR games, their correlation with learning outcomes, and the impact on the learning process. This paper follows the preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews (PRISMA-ScR) protocol. The findings suggest that simulation, role-playing, and problem-solving VR games are the most common, particularly in healthcare and science, technology, engineering, and mathematics (STEM) fields, improving engagement, retention, and skill development. The use of VR games in other fields and the needs of neurodiverse or physically disabled learners have yet to be explored. The review discusses the use of big data and cloud computing for VR deployment and adaption, and the significance of low and no-code technologies for educators developing VR without programming knowledge. Through the synthesis of patterns, research gaps, and cross-disciplinary challenges, this study provides a roadmap for VR-based gamification research, with emphasis on inclusivity, ethical considerations, long-term learning effectiveness beyond novelty effects, and sustainable educational integration.

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1. INTRODUCTION

The virtual reality (VR) concept has been recognized as a revolutionary educational technology that provides a platform for a more immersive and interactive learning experience compared to conventional teaching methodologies [1]. The integration of gamification elements with VR provides a platform for a more engaging learning experience, which has been recognized as a revolutionary concept for the field of education [2]. Recent advancements in the field of cloud computing and big data analysis have accelerated the adoption of VR, which provides a platform for a more personalized learning experience [3], [4]. Recent research has demonstrated the effectiveness of VR in the field of education. For example, the field of healthcare education has been significantly impacted by the adoption of VR, which provides a platform for simulating surgeries to a greater degree [5], [6]. Similarly, the field of science, technology, engineering, and mathematics (STEM) education has been impacted by the adoption of VR, which provides a platform for the exploration of abstract concepts such as physics, astronomy, and engineering [7]. Other fields impacted by

VR include construction safety, cultural sensitivity education, and digital humanities [8]-[10]. However, the impact of VR on the social sciences and humanities fields appears to be limited.

This notwithstanding, there exist a number of challenges to be addressed. First, the ability to develop a VR program requires programming and design knowledge, which acts as a barrier to those who do not possess this knowledge, such as educators [11], [12]. Second, the cost of the equipment acts as a barrier to the adoption of the technology, particularly in environments where resources are limited [13]. Third, the challenge lies in the fact that the integration of the curriculum with the open-ended nature of the immersive experience makes it difficult to integrate the standardized curriculum [14]. Other issues, such as the ethics of the cloud-based platform, inequality, and the needs of neurodivergent students and the physically challenged, are often ignored [15].

This study undertakes a scoping review of VR-based gamified learning from 2010-2025. The study analyzed 108 studies to answer the following research questions: i) What are the dominant VR games used in learning, and how are they aligned with learning objectives? ii) Which subjects benefit most from VR learning, and what are the outcomes of VR learning? iii) How has the advent of cloud computing and big data influenced VR development? and iv) What are the strategies adopted to make VR learning simple for educators who are not proficient programmers? The study contributes to the field of VR gamification by undertaking a synthesis of existing research on the topic and identifying areas of research that are yet to be explored. Contributions: the study makes two main contributions to the field of VR gamification: first, it undertakes a synthesis of existing research on VR-based gamified learning from 2010-2025, consisting of 108 studies on STEM, healthcare, and non-STEM disciplines. Second, it undertakes a critical comparative analysis of existing research on VR gamification by identifying thematic patterns, cross-disciplinary applications, and limitations of existing studies on VR gamification. Third, it highlights research gaps in ethics (privacy, equity, and digital divide), accessibility (neurodivergent and physically impaired learners), and underrepresented disciplines such as social sciences and humanities. Fourth, it evaluates enabling technologies, including big data and cloud computing, for scalability, personalization, and adaptive VR-based learning. Finally, it proposes practical recommendations for future VR gamification research and development, including the use of low-code and no-code tools to empower educators without programming expertise.

The current literature demonstrates that in the field of healthcare and STEM, the most frequent use of VR games is for simulation, role-playing, and problem-solving [16], regardless of their short-term positive impact on motivation and performance, although long-term retention is less evident [17]. In non-STEM fields, there have been positive results from early pilots in empathy, cultural awareness and language learning, although coverage is sparse [18]. Ethical and equity issues, such as data privacy, consent, and fairness, have not been adequately addressed [15]. Neurodiverse or visually impaired learners and universal design for accessibility have not yet been explored, and the latter has minimal implementation [19]. New trends include adaptive learning with big data and cloud computing and low-code or no-code authoring to empower non-programmer educators [20].

Study structure: in the study, the methods are presented in section 2, which includes the criteria for screening and analysis. In section 3, the findings are presented, which include the combination of bibliometric patterns and thematic synthesis. In section 4, the implications, ethical issues, and recommendations are presented, while the conclusions and the way forward are presented in section 5.

2. METHOD

The study followed a systematic approach to identify, analyze, and synthesize the research on the application of VR in education. For this purpose, the study followed the preferred reporting items for systematic reviews and meta-analyses–search extension (PRISMA-S) checklist [21]. Four databases were used to search the relevant literature, namely Scopus, Web of Science, IEEE Xplore, and Google Scholar. Relevant keywords were used to search the databases. Boolean operators like AND, OR, NOT were also used to search the relevant literature. Keywords like "Virtual Reality in education," "VR game types," "gamification in education," "VR and cloud computing," were used to search the relevant literature. The study reviewed the literature published between 2010 and 2025, including the articles published ahead of print.

The study followed a series of steps to screen the relevant literature. First, the title and abstract were screened based on the inclusion and exclusion criteria. After that, the full-text screening was done to assess the quality of the study.

A data extraction form was designed to extract essential data from the studies. The data included study objectives, methodologies, VR applications, game types, course coverage, outcomes, and challenges. Ultimately, 108 studies were included for the final review. Studies on the use of VR in education, the relationship between game types and educational objectives [22], and the use of big data and cloud computing technologies in VR tools [23] were reviewed.

A systematic review of the data was conducted qualitatively to identify the themes and trends of the data. The methodology is a rigorous way of understanding the impact of VR on various game types and courses of application, taking into consideration the technological and educational aspects of the data. The methodology is transparent and systematic, making the data credible.

2.1. Inclusion and exclusion criteria

The inclusion and exclusion criteria are as follows to select the studies:

Inclusion criteria:

– The studies were published between 2010 and 2025, including early access in 2025.
– The studies have focused on the applications of VR in education, specifically focusing on the integration of various types of games or course applications in education.
– The studies have focused on the role of big data, cloud computing, or interactive three-dimensional (3D) environments in the context of VR tools in education.
– The studies are in English, including peer-reviewed journals, conference papers, and book chapters.
– The studies have focused on the role of big data, cloud computing, or interactive 3D environments in the context of VR tools in education, offering insights into the application of VR in education.

Exclusion criteria:

– Investigations focused exclusively on entertainment or non-educational uses of VR.
– Non-academic sources, promotional articles, anecdotal reports, and blog posts.
– Literature not adhering to a rigorous research methodology or not of academic quality.
– Repeated studies that did not meet inclusion criteria.

Table 1 shows the quality appraisal results of the empirical studies included in this review based on the mixed methods appraisal tool (MMAT) criteria by study design category and criterion-level performance (S1-S2 and C1-C5).

Table 1. MMAT appraisal summary of the included studies

Category	N_Appraised	N_Failed_S1_or_S2	%Yes_C1	%Yes_C2	%Yes_C3	%Yes_C4	%Yes_C5
Mixed methods	3	0	0	0	66.7	66.7	66.7
Non-randomized	7	0	14.3	100	42.6	28.9	42.6
Qualitative	15	2	93	73	40	0	13
Quantitative descriptive	10	0	60	20	100	20	20
Randomized	4	0	75	25	25	0	0

Quality appraisal: the methodological quality of the empirical studies was assessed using the MMAT [24]. The two screening questions (S1–S2: are there clear research questions? Do the collected data address the research questions?) were applied to each study, followed by the five core criteria corresponding to the study design categories (qualitative, randomized controlled, nonrandomized, quantitative descriptive, and mixed methods). Disagreements were resolved through consensus. No overall score was calculated, in accordance with MMAT guidelines. Table 1 summarizes the appraisal results, including N_Appraised, %Yes for C1–C5, and the number of studies failing S1 or S2.

Figure 1 shows the PRISMA-ScR flow diagram for the study selection process. Initially, the total number of identified studies was 27,332 from four databases: Scopus, Web of Science, IEEE Xplore, and Google Scholar. However, after the application of the predefined filters and removal of duplicate studies (26,941), the total number of unique studies was 391. At this stage, 246 studies were excluded due to non-compliance with the predefined research criteria. Then, the search process identified 145 studies for the retrieval of the full text. However, five studies could not be retrieved due to non-accessibility. Therefore, the total number of studies was 140. Finally, after the application of the MMAT-based quality assessment tool, 32 studies were excluded due to non-compliance with the research criteria. At this stage, the studies were excluded due to non-relevance to VR (n=9), non-inclusion of an educational context (n=11), and thesis and abstract publications (n=12). Finally, the total number of studies was 108 after the application of the inclusion and exclusion criteria.

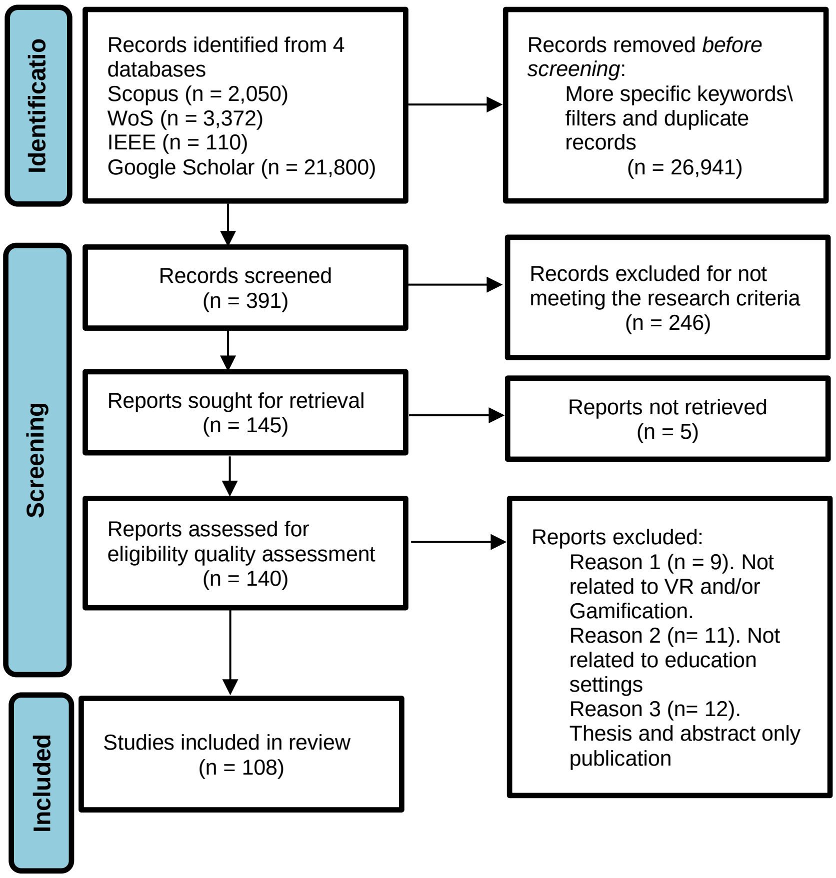

Figure 1. PRISMA-ScR flow diagram of the study selection

3. RESULT AND DISCUSSION

This section presents the main findings of the systematic review of the integration of VR into education between 2010 and 2025. It summarizes key information about the dataset, including document distribution, publication growth trends, author collaboration, and keyword analyses. The results offer a general overview of the research activities carried out and the developments achieved in different VR applications in the field of education.

In order to offer a different type of complementary information to the descriptive indicators presented, the results are grouped into: i) bibliometric trends, ii) thematic structures, and iii) representative integrations and gaps. This structure does not focus too much on the quantitative data, rather on what this data implies.

3.1. Main information

Table 2 shows the general characteristics of the dataset used in this review, including the publication time span, the number of sources, types of documents, collaboration measures, and keyword usage. These characteristics offer essential background information to help readers comprehend the spread of research on VR in education.

The total documents included in the dataset are 108, with 79 sources and a date range from 2010-2025, with 2025 including early access. The trends in VR education research have been shown, and the interest has had an increasing growth rate of 2.74%. The collaboration for documents is mild, with an average of 3.29 co-authors and 6.04% international co-authorships. Articles [2], [4], [6], [7], [9]–[11], [13]–[15], [17], [18], [20], [25]–[71] constitute the leading output, followed by reviews [8], [72]–[88] and conference papers [1], [5], [89]–[102], alongside book chapters [3], [103]–[109], books [110]–[113], and report [114].

Table 3 shows the significance of the conducted research regarding gamified education with the use of VR, which, despite the positive results, remains quite scattered, with the dominance of STEM fields and the complete absence of humanities. Although the positive effects on engagement and motivation are confirmed, the results regarding the retention of the acquired knowledge in the long run are quite scarce. In addition, the use of prototypes and context-specific designs also underscores the continuing lack of generalizability, scalability, and curriculum integration.

Table 2. Details of the studies

Description	Results
Timespan	2010:2025
Sources (Journals and Books)	79
Documents	108
Annual growth rate %	2.74
Document average age	4.67
Average citations per doc	21.81
Keywords plus (ID)	311
Author’s keywords (DE)	130
Authors	352
Authors of single-authored docs	19
Single-authored docs	19
Co-Authors per doc	3.29
International co-authorships %	6.04
Article	61
Book	4
Book chapter	8
Conference paper	16
Review	18
Report	1

Table 3. Top 10 influential studies on VR gamified education (2010–2025)

Ref.	Year	Venue/type	Discipline	Game type	Reported learning outcome	Notes
[61]	2022	Simulation and gaming/ article	History education	Gamification in VR activities (PBL/quests)	Enhances engagement and motivation	Empirical focus on history learning with gamified VR use
[89]	2020	Conference paper	Architecture/urban design	City-building VR/AR gamification	Enhances motivation; and supports practice of design skills	Studio-style learning with gamified tasks in VR/AR
[76]	2023	Review	Medical/anatomy education	Various (review)	Synthesis: enhances engagement with frequent knowledge gains	Systematic review spanning VR+ gamified strategies
[28]	2023	Engineering proceedings article	Higher education /EdTech	Gamified VR coursework (PBL/challenges)	Enhances engagement; positive student feedback	Case study comparing gamified VR class formats
[25]	2022	Article	Industrial design	Gamified VR/ AR studio tasks	Enhance engagement and spatial understanding	Field synthesis with applied examples
[92]	2024	Conference paper	Higher education (general)	Framework-level gamification	Aims to enhance engagement (conceptual; no measured outcomes)	Design-thinking/Education 5.0 framing
[93]	2024	Conference paper	Interdisciplinary (education/neuro)	Neuro-informed gamified VR	Theorize enhanced learning benefits (Conceptual/prototype)	Model links cognitive factors to gamified VR
[75]	2024	Review	Cross-disciplinary	Various (review)	Synthesis: enhances engagement/motivation; mixed effects on achievement	Highlights design/implementati on challenges
[90]	2023	Conference paper	Engineering/ Education	Gamified VR challenges	Enhance critical thinking and engagement	Classroom intervention in VR with gamified tasks
[82]	2023	Review	Cross-disciplinary	Various (review)	Synthesis: enhances learning and retention	Broad review; includes gamified VR evidence

3.2. Annual scientific productions

Figure 2 shows the annual scientific production regarding VR in the field of education from 2010-2025. The trend shows a steady increase in publications over the years, with a marked acceleration after 2018. This increase in publications can be explained by the development of technology regarding VR equipment, the availability of development tools, and the global shift to virtual learning environments due to the COVID-19 pandemic. The steady growth in publications reflects the maturity of VR as a legitimate field of research in education, as opposed to a novelty-driven innovation. The steady growth in publications, however, does not necessarily mean that the quality of publications has grown proportionally, which warrants further research.

The graph reveals increasing research interest in VR education, showing an upward trend in annual scientific production from 2010-2025. After 2018, growth was significant [28], [29], [92], [93]. This trend suggests an increasing contribution of VR to scholarly work and, thus, its growing use in educational research and technology.

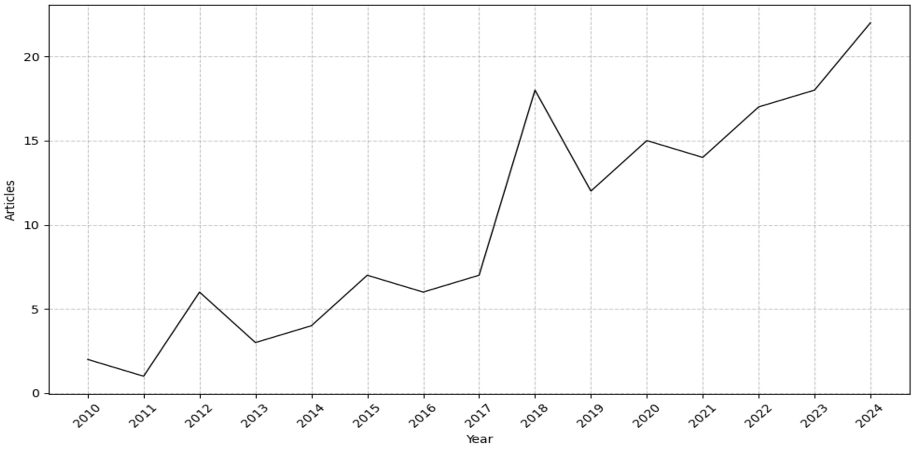

Figure 2. Annual scientific production in VR and education research (2010–2025)

3.3. Average citations per year

Figure 3 shows a plot of the average citations received by publications related to VR in the field of education from 2010-2025. There was a peak in the citations around 2015, which could be an indication of the publication of highly influential foundational works around this time. This could be an indication of the novelty stage of the development of the field of immersive learning, where pioneering works received a lot of attention from researchers.

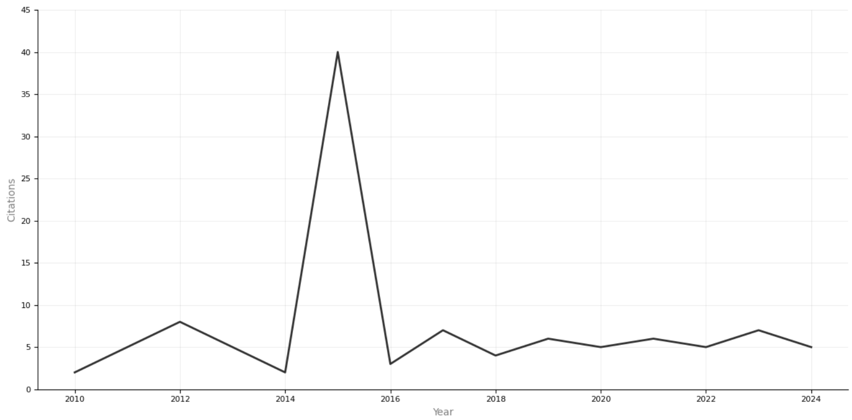

Figure 3. Average citations per year in VR-education research (2010–2025)

After this time, although the number of publications continued to grow, the average citation rate of publications shows a sense of stabilization and fluctuation. This shows a development from a highly cited set of foundational works to a more diversified field of publications. The difference in the rate of growth of publications (Figure 2) and the rate of citation shows that the field of publications has grown, but the high-impact influence of publications has remained a selective area of focus.

3.4. Word cloud

Figure 4 illustrates the most frequently used words in the reviewed literature, with the size of the words indicating the frequency. The prominence of words such as “Virtual Reality,” “Gamification,” “Students,” “Learning,” and “Education” again reinforces the learner-centric nature of the research. The prominence of words such as “Engineering Education,” “Medical Education,” and “E-Learning” again reinforces the focus of VR research in the fields of STEM and health education. Notably, words such as “Ethics,” “Accessibility,” “Universal Design,” and “Social Sciences” appear less frequently and/or play less significant roles in the research. Hence, the word cloud not only represents the research priorities but also visually indicates the gaps in the research.

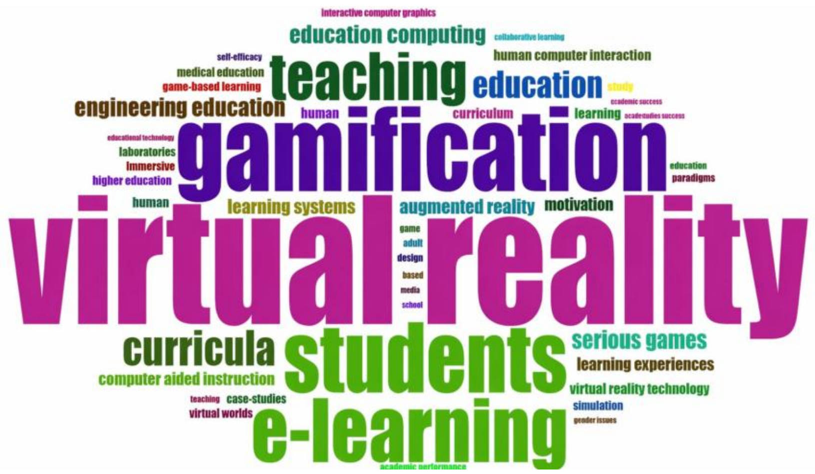

Figure 4. Word cloud visualization of frequent terms in VR and education research

3.5. Trends topic

Table 4 shows the most popular topics in the research on VR education, along with the key years these topics have dominated. It shows the evolution of these concepts over time, which can include new areas of interest as well as established areas.

Table 4. Top occurring terms with their frequencies and temporal distributions

Term	Frequency	Year (Q1)	Year (Median)	Year (Q3)
Education	14	2015	2016	2018
Motivation	7	2014	2016	2018
Medical education	5	2018	2018	2024
Computer aided instruction	7	2015	2019	2022
Curriculum	6	2018	2019	2019
Learning	6	2018	2019	2020
Students	35	2016	2020	2022
Teaching	24	2016	2020	2023
Education computing	10	2016	2020	2022
VR	64	2018	2021	2023
E-Learning	33	2019	2021	2023
Engineering education	10	2017	2021	2024
Gamification	42	2018	2022	2023
Curricula	18	2017	2022	2023
Augmented reality	8	2022	2022	2023
Learning systems	8	2021	2023	2023
Case-studies	5	2022	2023	2023
Immersive	5	2022	2023	2024

The table shows the distribution of the topics' frequencies over time. Some topics, such as "Virtual Reality" and "Gamification," demonstrate steady growth trends, especially over the recent period, while others show irregular trends. This distribution of topics over time demonstrates the growth of interest and trends within the VR education research domain.

3.6. Clusters of thematic map

The thematic map clusters identified in Table 5 represent central and peripheral themes that differ in terms of maturity levels. These have centrality, density, and frequency measures, which help in understanding the thematic significance and maturity levels.

Table 5. Clusters were extracted from the thematic map based on their centrality, density, and frequency

Cluster	Callon centrality	Callon density	Rank centrality	Rank density	Cluster frequency
Education	5.039	189.18	5	6	85
VR	13.269	114.411	6	5	466
Contrastive learning	0.75	93.75	3.5	4	8
Hybrid systems	0.75	62.5	3.5	2	4
Metaverses	0.25	50	1	1	2
Knowledge	0.694	81.25	2	3	9

"Virtual Reality" has the highest Callon and rank centrality, which again affirms its prominent position in the thematic network. "Education" has the highest density, which shows that it has been well developed as a cluster. Clusters with low centrality and density, such as "Metaverse," seem to be less prominent.

Overall, the thematic structure appears to indicate that "Virtual Reality," "Education," and "Gamification" are all motor themes, signifying the core of the field. The "Simulation" and "Assessment" clusters can be seen as consolidating to applied skill development and evaluation, respectively. The lower centrality of certain themes appears to indicate niche areas of development, which are not yet integrated into mainstream practice, and thus require further theory-based research to inform practice.

3.7. Detailed analysis of virtual reality integrations

Table 6 shows how various VR game genres address subject-specific goals through various technological means. For instance, multiplayer and adventure games are beneficial for developing collaboration skills and exploration habits. Medical simulations are beneficial for developing realistic skills, while role-playing games are beneficial for developing empathy skills but are characterized by interactivity challenges. Puzzle VR games are beneficial for spatial skills development but are characterized by curriculum alignment challenges. Overall, various VR game genres are characterized by various distinct benefits and challenges associated with their integration into the curriculum.

Table 6. VR game types, educational applications, and the associated design and pedagogical challenges

Game type	VR mode	Course/subject	Learning objective	Technological features	Challenges in VR design	Challenges in educational
Multiplayer game	Networked VR	Robotics/ engineering	Collaborate mechanical design	Object control and synchronous communication	User tracking and multiplayer lag	Group dynamics and instructor mediation
Adventure game	Immersive VR	Geography and environmental science	Ecosystems and Human interaction	Interactive maps and open-world VR	Resource-intensive environments	Knowledge gains and assessment gaps
Simulation game	Full VR with haptics	Nursing/ medicine	Emergency response and surgical training	Simulations and haptics	Extreme development and equipment cost	Adaptation challenges and learning standards
Role-playing game	Desktop VR/360° video	Social science or history	Event sequencing and historical empathy	Character interaction and virtual timelines	Lack of interactivity in video-based formats	Evaluation gaps and cultural gaps
Puzzle/ problem solving	Immersive VR	Mathematics (algebra and geometry)	Spatial reasoning and logical thinking	3D interaction and motion tracking	High specs and motion sickness	Curriculum misalignment and abstract complexity

3.8. Gap matrix across game types and research needs

To surface underexplored intersections, Table 7 summarizes gaps across game types, longitudinal evidence, accessibility, ethics, and course coverage.

Table 7. Gap matrix across game types×research needs

Game type	Longitudinal evidence	Accessibility/UDL coverage	Ethics/privacy coverage	Underexplored courses	Noted challenges
Simulation	Rare (short-term dominant)	Limited (haptics not inclusive)	Limited reporting and data handling	Humanities and K–12 early grades	High cost; generalization issues
Role-playing	Rare	Moderate (narrative aids inclusion)	Sparse	STEM lab courses	Assessment alignment; fidelity vs. time
Puzzle/ challenge	Rare	Limited	Sparse	Health skills, Teacher Ed.	Shallow transfer; over-gamification risk
Adventure/ exploration	Very rare	Limited (motion sickness)	Sparse	Formal CS theory and advanced math	Open-world scope; cognitive load
Strategy	Rare	Limited	Sparse	Primary education	Complexity; scaffolding demands
Open-world	Very rare	Limited	Sparse	Applied engineering labs	Performance benchmarking; resource intensive

3.9. Trend of virtual reality games in education

VR games have revolutionized the education sector with immersive and interactive experiences [103]. The use of VR games in education has grown rapidly in recent years and the trend is expected to continue with advancements in hardware, software, and technology. While traditionally VR games have been used in specific areas such as aviation and medicine, they have now been incorporated in mainstream subjects such as mathematics, geography, and science. Simulation games have been effective in healthcare, engineering, and flight simulation [73]; exploration games have been effective in subjects such as biology and geography [77]; and puzzle games have been effective in enhancing cognitive abilities, especially in subjects such as STEM [91]. The availability of more VR devices has further helped in enhancing motivation, engagement, retention, and content. Figure 5 illustrates the growth of VR games in the education sector, with an increase in adoption from less than 1% in 2010 to 33% in 2023. The graph indicates steady growth between 2015 and 2020, and an exponential increase after 2020. The growth has, however, stabilized since 2021, indicating that the trend has moved from early adoption to widespread adoption, with VR games being recognized as an essential tool in the education sector.

Figure 5 presents the growth trend of the adoption of VR gamification in the educational literature from 2010-2025, according to the distribution of the literature included in this review article. It is evident that the adoption of VR gamification in the educational literature was limited until 2014, which is attributed to the early stages of the development and implementation of immersive technologies in the educational sector.

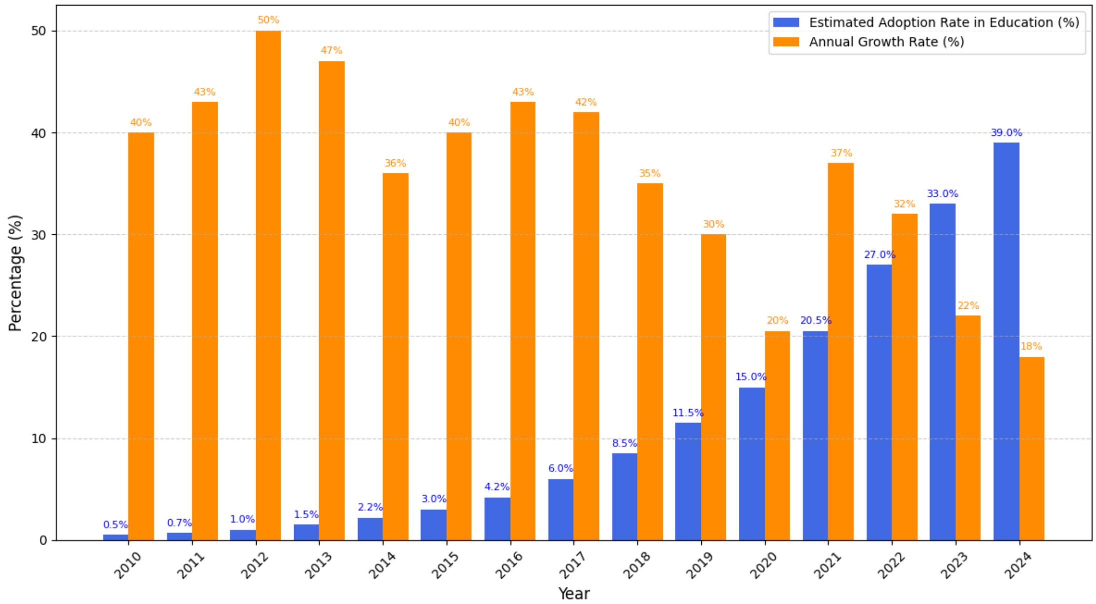

Figure 5. Trend and growth rate of VR game adoption in education (2010–2025)

A steady growth trend is evident in the literature from 2015 to 2020, which is attributed to the development and implementation of affordable VR technology and the development of digital learning strategies in the educational sector. A sharp growth trend is evident in the literature from 2020 onwards, which is attributed to the global shift to remote and technology-enhanced learning in response to the COVID-19 pandemic. A stable growth trend is evident in the literature from 2023 onwards, which is attributed to the transition from the experimental implementation of VR gamification in the educational sector to its mainstreaming in the pedagogical process in the higher educational sector.

3.10. Predominant types and applications of virtual reality games in education

A key finding in VR gamification research is that education gamified in VR is seen in various games, such as simulation-based games and immersive exploration environments. For example, simulation games have become especially common in fields such as medicine, engineering, and aviation Stone *et al*. [91]. These games contextualize what learners are learning in practical, skill-based learning objectives, allowing students to practice performing procedures or tasks in ways without risk within the virtual environment. For instance, students can experience the real world without physical resource restraints, such as virtual surgeries and laboratory simulations [30]. Simulations embody a hands-on approach consistent with experiential learning theories, where concepts are further understood through repetition and practice.

For example, exploration-based VR games are already suitable for history, geography, or science classes Orasi and Sameshima [31]. It is possible to use these games to work with dynamic 3D virtual worlds to explore historical landmarks, natural ecosystems, or the universe Korkut and Surer [77]. The exploration of curiosity and interactive learning is beneficial for increasing retention rates. For example, virtual tours of ancient Egypt can offer learners a unique experience rather than depending on books Abdelmonem [114]. According to Bloom's taxonomy of education, this experience is on the knowledge or application level.

The development of skills such as critical thinking, logic, or problem-solving skills is possible through puzzle-based VR games [90]. For example, challenges can include complex mathematical equations or chemical reactions in a VR game. The VR-based puzzles are aligned with cognitive learning outcomes and can provide instant scoring, thus promoting learning [94].

Finally, the suitability of certain game types to learning objectives confirms the flexibility of VR tools for learning purposes. Regardless of whether the VR game is a simulation, exploration, or puzzle game, VR tools offer a personal learning experience that increases academic performance and motivation [6], [56], [94]. As demonstrated by Figure 6, the majority of studies on VR games focus on simulations, explorations, and puzzle games.

Figure 6 shows the proportion of the VR game types identified from the 108 studies reviewed in this paper. It is obvious that most of the studies focus on developing simulation VR games, which is approximately 45%, particularly for medicine, engineering, and aviation-related fields.

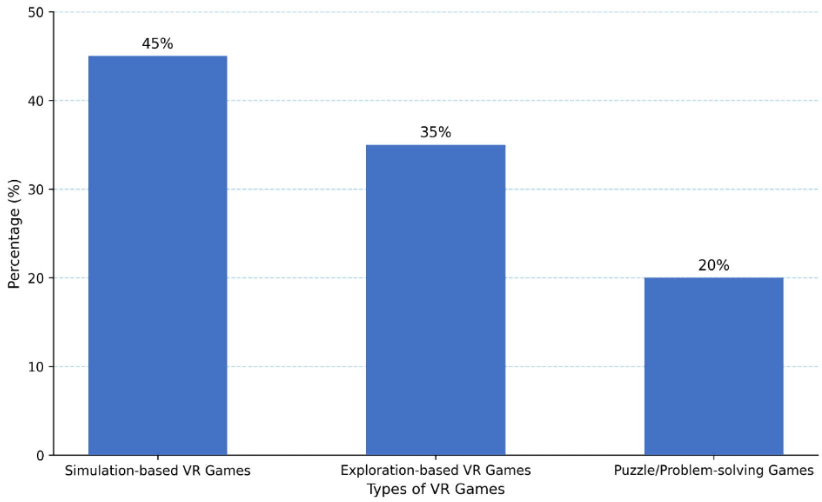

Figure 6. Distribution of VR game types applied in educational research

The exploration-based VR environment has accounted for about 35%, particularly in geography, environment, and history education. The puzzle-based VR game has accounted for about 20%, particularly in STEM education for enhancing logical thinking skills among users. It is evident that the majority of the VR games have focused on experiential learning, while strategy-based VR games have remained underexplored.

3.10.1. Areas benefiting from virtual reality integration and learning outcomes

VR adoption significantly affects subject areas, namely healthcare STEM and arts education [18]. VR has and will continue to transform healthcare education. High-fidelity simulations teach students anatomy, medical procedures, and surgical techniques [78]. For example, VR tools allow medical students to practice complicated surgery multiple times without real-world stakes, increasing procedural accuracy and decreasing errors [6]. Additionally, studies have shown that students applying VR-based learning platforms have better retention and comprehension than traditional methods [104].

The benefits of STEM (mainly engineering and physics) education have also been observed [32]. Learners can examine mechanical packages, physical phenomena, and architectural models via virtual laboratories in an interactive and controlled setting [79]. With this ability, students can test hypotheses, build models, and simulate large-scale and highly impractical experiments in a physical laboratory. VR's ability to visualize abstract concepts like molecular structures or gravitational force fills student's knowledge gaps and increases conceptual clarity [33].

The interactive 3D capability of VR is put to practice in arts and design education to encourage creativity and design thinking. Students use virtual painting tools, 3D modeling software, and immersive theater environments to practice skills they cannot practice traditionally [34]. Yet, particularly for all graphic design and architecture students who require immersive tools to explore and collaborate.

However, the observed improvements in the learning outcomes in these disciplines include improved student engagement, better understanding of concepts, and better academic performance. VR's immersive nature makes the participants active, which can help with knowledge retention.

3.10.2. Role of big data and cloud computing in virtual reality development and scalability

Large-scale data and cloud computing are critical for moving forward with VR tools in education to solve the problems of scalability, data storage, and personalization [70]. For instance, big data analytics has allowed educators to obtain and evaluate large amounts of user interaction data in VR environments [35]. With the ability to track when students' complete parts of games, for how long they spend on them, or which parts of games are complex, educators can create personalized content tailored to each student's learning. Looking at VR usage patterns enables insights into how weaknesses in curriculum delivery can be highlighted, enabling the provision of specific solutions to support performance enhancement [17].

VR educational tools may be supported by storage, processing, and distribution through cloud computing [36]. Typically, VR applications are hindered by hardware requirements and local storage Lai *et al*. [95]. However, access to VR tools has become more scalable and cost-effective due to cloud-based solutions [105]. Educational institutions can deploy VR platforms via cloud servers for remote learning and collaborative experiences from geographically distributed contexts [37]. The strong scalability of these approaches is especially useful for higher-education institutions that provide distance-learning programs.

For example, a cloud-based platform provides students worldwide access to VR tools for collaborative experiments in science [80]. Integrating such services alleviates the local computing resource burden and provides good user experience at an affordable cost to educational institutions. Additionally, VR is ideal for adaptive learning systems that leverage big data and cloud-based solutions [38]. By analyzing real-time data, these systems modulate game difficulty or content according to each learner's progress to provide personalized and dynamic education.

3.10.3. Simplifying virtual reality development for non-programming educators

A significant hurdle to VR uses in education is the difficulty in developing games, especially for those without programming skills, such as educators and other developers. Most VR tools require a certain level of coding expertise, which creates a barrier. However, several strategies can simplify the development process and encourage its widespread adoption. No-code or low-code platforms: fortunately, due to recent improvements, intuitive VR development platforms require no coding knowledge to create [20]. Educators can develop interactive VR environments using drag-and-drop features through Unity, which has visual scripting features and VR authoring software [96]. This democratizes VR content creation, allowing teachers to teach rather than craft technical skills. Pre-designed VR templates: this process can be simplified by developing subject-specific VR templates. An example would be ready-made VR templates for the biology lab, history tours, or math puzzles, which educators can customize and use instead of creating them from scratch [110]. These templates save time and resources so that the teachers can easily make VR tools a part of the activities. Training and capacity-building programs: educators are given workshops and professional development programs on VR adoption to help them acquire the basic skills required to work on VR platforms [72]. Such training can be performed in partnership with technology providers and universities, creating opportunities to interleave instruction and developer work, and bringing together educators and developers.

Artificial intelligence (AI-powered) game creation: AI tools can mimic specific aspects of VR game development, such as creating 3D assets, designing levels, personalizing user experiences, or a mix of these [39]. For example, concept repetition in learning content can be addressed by implementing AI-driven systems that create learning content based on predefined educational objectives, thus removing the need for manual coding of the content [81]. By implementing these methods, educators who do not possess technical skills can become part of the design and VR game development, which will facilitate the integration of VR tools in classrooms more broadly.

3.10.4. Rationale for developing a cybersecurity-specific virtual reality model

This study was based on the development of a new VR model of education, particularly for cybersecurity training, given the increasing intricacy of cybersecurity threats. The usual approaches to learning are considered ineffective in the provision of the necessary experiences to stimulate cyber-attack situations [74]. Furthermore, this gap can potentially be addressed through a VR environment since learners can practice offensive and defensive cybersecurity techniques without exposing any real systems to potential damage [106]. As a result, VR-assisted adaptive learning, scenario learning, and feedback are considered potentially essential tools for preparing learners to handle dynamic changes in cybersecurity threats [40]. In the digital age of today, given the importance of cybersecurity, particularly within various sectors of the economy such as national security, healthcare, and finance, there is a growing need for effective and innovative learning tools [41]. Lastly, this study will help address the existing challenges within cybersecurity learning as well as promote skill development within a controlled VR environment.

4. DISCUSSIONS

This section critically interprets the findings of the review (RQ1–RQ4), linking them to broader pedagogical, ethical, accessibility, and cross-disciplinary perspectives.

4.1. Pedagogical implications

The prominence of simulation and adventure-based VR games (RQ1 and RQ2) supports the idea of the effectiveness of immersive environments in experiential and skill-based learning. These results are in line with the constructivist and experiential learning theories, supporting the idea of experiential learning, in which learners are actively engaged in constructing their knowledge, not just observing it. Although short-term effects on motivation and engagement are consistently reported, particularly in STEM and healthcare domains, little focus is given to the long-term effects of these, indicating a need to explore this area in the future. The development of adaptive feedback mechanisms, although not explored, may enhance the balance between challenge and cognitive load, a fundamental component of gamification [6], [42]–[47], [72], [79], [83], [112].

The anchoring of these patterns to educational theory helps explain why the benefits seem short-term: the simulation aspect fits with experiential learning and practice, while autonomy and competence from adventure and puzzle game mechanics fit with self-determination theory. The benefits are also consistent with constructivist theory, where learners engage with rich representations to actively construct knowledge structures. However, high challenge density and time pressure can lead to high extraneous cognitive load, making scaffolding and feedback critical to long-term transfer [48], [49], [83], [86], [89], [90], [97].

4.2. Ethical and equity challenges

Issues of ethics were rarely addressed within the current body of study (RQ4). For example, no study focused on issues of privacy, security, and cultural issues, even though some VR environments collect biometric and behavioral information. In addition, issues of equity were rarely addressed, including the limited focus on the impact of socioeconomic differences on access to the learning process using the VR gamification. These issues call for concerns about the inclusiveness of the application of the gamification process using the VR. It is essential to address these issues to help policymakers who seek to ensure the avoidance of digital inequality [13], [15], [50]–[52], [84], [86], [98], [99].

Actionable safeguards would cover data flows such as privacy by designing data flows (collection minimization and data processing on the device where feasible), consent for telemetry data, short retention periods, and role-based access to analytical dashboards. Equity would be achieved by operationalizing device provisioning/loaners, offline/low-bandwidth operation, and bias analysis for adaptive difficulty adjustment to prevent certain learners from being unfairly disadvantaged [43], [53], [54], [100], [109].

4.3. Accessibility and universal design

One of the significant gaps is related to the accessibility of different learning methods. Even with the increasing awareness of universal design and web content accessibility guidelines (WCAG) standards, fewer than 10% of the reviewed studies included provisions for neurodivergent and physically impaired students (RQ4). This demonstrates a lack of engagement with inclusive education principles within VR gamification studies. The inclusion of voice guidance and other provisions would not only increase the scope of VR learning beyond the realm of the physically able [43], [55], [56], [75], [84].

Using the universal design for learning, the VR content should include text or audio captions, alternative input methods (controllers, gaze, and voice), comfort settings (snap turn, vignette, seated or standing), and multiple means of engagement and assessment. Accessibility testing with diverse users has to be integrated into the design process, not done as an afterthought [53], [54], [85], [87], [107], [108], [112].

4.4. Cross-disciplinary insights

The majority of the VR gamification studies are still limited to the fields of STEM and healthcare domains (RQ2). The fields of humanities and social sciences are not represented well, although the few studies available indicate good results for empathy learning, cultural knowledge, and language acquisition. It is recommended that future studies expand the scope of VR gamification beyond the fields of STEM to discover new educational possibilities and reveal the general educational potential of VR gamification.

Additionally, new opportunities are opening up with the advent of AI and VR, which can create adaptive learning experiences. This is an emerging area and holds promise for future VR gamification studies. On the other hand, cloud computing and big data technology are providing new opportunities for the scalability of VR technology and real-time adaptive analytics, which can create more sustainable VR gamification experiences for a wide range of applications (RQ3) [57]–[60], [79], [81].

Promising cross-disciplinary pilots involve role plays for ethics/civic reasoning, place-based exploration for history/archaeology, and embodied visualizations for abstract math. From a methodological perspective, mixed-measures approaches that integrate performance tasks with transfer and retention tests hold the potential to establish value beyond novelty effects [61]–[65], [101], [113].

4.5. Summary of key insights

In summary, the review highlights both progress and persistent gaps:

- Pedagogical benefits are evident in short-term engagement and performance, but long-term effects remain unclear.
- Ethical and equity issues are insufficiently addressed, raising concerns about privacy, and fairness.
- Accessibility and universal design are rarely implemented, limiting inclusivity.
- Cross-disciplinary applications outside STEM are scarce but highly promising.

These findings highlight that VR gamification in education is effective but still evolving and requires further research. Addressing these identified gaps is essential for transforming VR into a sustainable, inclusive and ethical educational tool. Collectively, these insights support a concise, practice-oriented conclusion and focused agenda for future research.

5. CONCLUSION

VR-based gamification is transforming education by maximizing engagement, retention, and learning outcomes in areas like health, STEM fields, and arts. The simulations, exploratory experiences, and game-based puzzles help build skills, clarify complex concepts, and enhance creativity. Big data and cloud computing are also supporting the education transformation by personalizing learning, analytics, and affordable VR-based solutions. This review contributes by: i) linking game types with learning outcomes for the 2010-2025 period, ii) synthesizing methodological patterns for understanding the dynamics of short-term vs. sustained effects, and iii) uncovering design and policy interventions for inclusive adoption.

From the theoretical side, VR supports the constructivist and experiential learning theories by enabling learners to build their own knowledge through simulation. It also supports the experiential learning cycle by linking the conceptual and the practical. These theories are also aligned with the cognitive load theories, which state that an adaptive system can change the content based on the learner’s progression. This is particularly useful in the fields of health and STEM education, as learners can repeatedly practice simulations without risk. To implement VR in the present day, educators can use curriculum-based scenarios with scaffolded challenges, UDL-based comfort and input designs, data practices based on privacy by design, and low-code authority for non-programmers.

In practical terms, VR enables educators and learning organizations to use immersive experiences for collaboration and knowledge retention. It also enables application developers to leverage cloud scalability and analytics-based adaptive technologies. To make VR more accessible, the technical barrier is reduced through the use of drag-and-drop technologies and templates. This allows non-programmers to use the technology. In areas with limited resources, the use of virtual technologies promotes education through the use of virtual labs and simulations. Overall, the use of VR-based gamification challenges traditional education by integrating interactivity, personalization, and experience-based learning into its core. This creates the potential for an inclusive, innovative, and global education paradigm.

Future studies can address the identified gaps by focusing on the longitudinal evaluation of the effects of VR-based learning on performance and engagement, exploring learning platforms for non-technical educators, and examining the effectiveness of big data and AI personalization for optimizing adaptive learning. Expanding the scope of VR learning platforms for non-traditional fields such as the social sciences and humanities, while addressing the ethical implications for privacy, accessibility, and inclusivity, would be vital for the growth of the technology. In particular, the following would be the priority for the expansion and development of the VR learning platforms:

Limitations: this study, as a scoping review, has the limitations that it presents the breadth of the information collected, as opposed to the effect size, which might be limited by the fact that the information collected was only based on English literature and might be heterogeneous in the measures used.

ACKNOWLEDGMENT

The authors are grateful to Universiti Sains Malaysia for funding this research. with the grant number: Short-Term Grant: 304/PKOMP/6315801. AI-assisted tools ChatGPT and language-editing software QuillBot were used solely for language refinement and clarity. The authors take full responsibility for the content.

FUNDING INFORMATION

This research was funded by Universiti Sains Malaysia under the short-Term Grant (Grant No: 304/PKOMP/6315801).

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
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O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY

Data availability is not applicable to this study as no new data were generated or analyzed.

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