SYSTEMATIC / NARRATIVE REVIEW ARTICLE

Unlocking the potential of augmented reality (AR) in education: Insights from a systematic review of AR-enhanced instructional approaches

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ABSTRACT

Introduction: This review explores instructional approaches for AR-enhanced learning to improve student motivation, engagement, and learning outcomes. With AR technology gaining momentum, educators aim to implement best practices that leverage its benefits in diverse subject areas.

Materials and Methods: Using a systematic review approach and following PRISMA guidelines, this study analyzed 26 peer-reviewed articles published from 2014 to 2024.

Results: Findings were grouped around three central themes: AR's impact on learning and motivation, instructional approaches that support AR integration, and barriers to AR adoption in educational contexts. The analysis suggests that inquiry-based and collaborative approaches with AR improve student engagement, understanding, and academic performance. These results underscore the need for thoughtfully designed AR activities that provide a balance between student autonomy and guided instruction to avoid cognitive overload. However, challenges like accessibility, inclusivity, and limited resources remain obstacles to broader implementation, especially in under-resourced areas.

Conclusion: Future research should concentrate on developing standardized frameworks for AR in education, improving inclusivity, and assessing AR's long-term impact on learning outcomes across various educational settings.

KEYWORDS:
Instructional strategies, augmented reality, educational approaches, education

INTRODUCTION

Augmented reality (AR) has the capability to transform the learning experience by introducing an interactive and immersive dimension that extends beyond traditional educational practices. Integrating AR in educational settings helps learners see abstract ideas, experience through hands-on activities, and interact with three-dimensional models that enhance their learning.[1] These technologies are especially promising in disciplines such as science, medicine, and engineering, where spatial visualization is essential. Their potential motivates educators to explore how AR can enhance comprehension and engagement in such contexts.[2] The rapid rise of digital tools and the global shift toward technology-enhanced learning indicate a need to investigate effective instructional strategies for optimizing AR use in education.

Research in this area has shown that AR effectively boosts learning outcomes, focusing on increasing student engagement and long-term memory of complex information. For example, research has demonstrated AR can develop students' spatial ability and foster deeper understanding because they can manipulate 3D models in real time.[3] AR has additionally been proven to enhance motivation, specifically in health sciences and engineering disciplines that require an abstract concept visualization. AR-based interventions are only as effective as how well that technology is integrated into the instructional design. Studies comparing self-directed exploration with instructor-guided AR experiences have produced mixed results regarding which approach yields better learning benefits.[4]

Despite encouraging results, many aspects of AR integration remain unexplored and warrant further investigation. One of the main struggles is figuring out which type works in what educational setting and learning objectives. AR technologies vary widely—from mobile applications to fully immersive environments—making it challenging to compile a comprehensive classification of instructional approaches. Additionally, studies have found that AR technologies lead to better engagement and understanding; however, there is a lack of consensus regarding the balance between self-directed experiences and guided learning approaches. While some studies indicate that too much AR-based learning freedom might cause cognitive overload, others argue that guided approaches could restrain creativity and underuse technology features.[5] These issues are unresolved.

To maximize the educational benefits of AR, it is crucial to identify the instructional strategies that most effectively support its implementation. This study addresses that need by systematically reviewing existing research to determine effective instructional approaches for AR-based learning. Specifically, it seeks to answer the research question: What are the most effective instructional strategies for optimizing AR to enhance student performance, engagement, and comprehension across diverse educational contexts? The

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findings aim to synthesize current evidence, highlight pedagogical implications, and provide practical recommendations for educators and instructional designers seeking to integrate AR meaningfully into teaching and learning.

MATERIALS AND METHODS

Identification

This study followed established systematic review protocols to identify relevant studies. After selecting the main keywords, related synonyms were identified using dictionaries, encyclopaedias, and prior studies. These were used to develop search strings for the Scopus, Web of Science, and ERIC databases (see Table I). The systematic literature review was built on three databases: Scopus, Web of Science, and ERIC, which provide a solid basis to identify the main high-quality research in augmented reality (AR) applications in education.

The systematic search was conducted across three major databases: Scopus, Web of Science, and ERIC. Scopus provided extensive coverage of peer-reviewed interdisciplinary studies, Web of Science ensured high-quality indexed research, and ERIC contributed depth in educational and pedagogical studies.[6] Using these databases ensured wide disciplinary coverage and enhanced the comprehensiveness of the review. This process substantiates the credibility of the review by providing a broad range of studies, that are statistically significant and representative of the present orientation on AR in education. A total of 776 papers relevant to the study question in the first review stage from all three databases' references.

Screening

In the screening phase, relevant studies are assessed to confirm they meet the predefined research question(s). Studies focusing on instructional strategies and best approaches for AR in education while removing duplicate entries. Initially, 573 publications were excluded, leaving 203 papers for further review. (as shown in Table II). The initial criterion focused on peer-reviewed journal literature to ensure the inclusion of studies with rigorous methodological quality, transparent reporting, and replicability. Conference papers, book chapters, and dissertations were excluded because they often lack detailed methodology, may not be peer-reviewed, and vary in academic rigor. These exclusions-maintained consistency and reliability across the studies reviewed, thereby strengthening the validity of the systematic synthesis. In this review, only English-language papers published between 2014 and 2024 were included. All identified references were imported into Mendeley to organize citations, remove duplicates efficiently and ensure a systematic screening workflow. Ultimately, 59 papers were excluded for duplication.

Eligibility

In the third phase, the eligibility stage, 144 articles were selected. Titles and abstracts of the retrieved articles were screened to determine if they met inclusion criteria as per research objectives. As a result, 118 articles were excluded due to being out of the relevant field, having irrelevant titles and abstracts unrelated to the objectives, or lacking full access even with empirical evidence available. In total, 26 articles were included and finally reviewed.

Quality Appraisal

To ensure external validity, the inclusion of all 26 papers was independently reviewed by three reviewers. The reviewers applied the Critical Appraisal Skills Program (CASP) checklist containing eight criteria (Table III). It was assessed using a quality appraisal by experts with over 10 years of experience in educational technology within academic institutions. It was used as a checklist to appraise the quality of studies derived from different types of evidence.[7] Quality appraisal was rated on three levels: excellent, sound, and moderate. Each article was evaluated based on clarity of research aims, methodological appropriateness, data collection relevance, and suitability of analysis techniques. In cases where there were discrepancies in scoring, the reviewers engaged in discussion to reach a consensus. If disagreement remained unresolved, a fourth independent reviewer was consulted to make the final decision. This consensus process ensured consistency and minimized bias in the quality evaluation. Following the quality appraisal, all 26 articles were reviewed, as summarized in Table III.

Data Abstraction and Analysis

An integrative analysis approach was used to synthesise studies with diverse research designs, particularly quantitative methods, to identify main themes and subthemes. The first step in theme development was data collection. Following this, the authors reviewed significant existing studies on instructional strategies and best approaches for augmented reality in education, examining the methodologies and research outcomes. The authors then worked collaboratively to create themes based on the evidence within the study's context. A reflective log was maintained to document analytical decisions, challenges, and interpretations. Results were then compared to identify any discrepancies in theme development. When there were conceptual disagreements, the authors discussed them to a mutual consensus.

Additionally, the authors discussed and resolved differences in the coding process by comparing these results during theme development. The authors discussed any discrepancies. In the end, themes were refined for consistency. Three experts—two in educational technology and one in instructional design—validated the identified themes to ensure clarity, relevance, and domain validity. Adjustments were made based on expert feedback.

The questions are as follows below:

1. How does the use of augmented reality (AR) technology influence learning outcomes and motivation among health professional students compared to traditional learning methods?
2. What are the most effective instructional approaches for implementing augmented reality (AR) to enhance students' comprehension and engagement in anatomy education?
3. What are the primary challenges and limitations of using augmented reality (AR) in higher education, and how do these factors affect its effectiveness in enhancing learning outcomes?

Table I: The Search String

Scopus	TITLE-ABS-KEY (("learn* approach*" OR "learn* technique*" OR "instructional technique*" OR "teach* strategie*" OR "instructional strategie*") AND ("augmented reality") AND ("education")) AND (LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2024)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE, "English"))
Wos	("learn* approach*" OR "learn* technique*" OR "instructional technique*" OR "teach* strategie*" OR "instructional strategie*") AND ("augmented reality") AND ("education") (Topic) and 2024 or 2023 or 2022 or 2021 or 2020 or 2019 or 2018 or 2017 or 2016 or 2015 or 2014 (Final Publication Year) and Article (Document Types) and English (Languages)
ERIC	augmented reality AND ("learning approaches" OR "instructional techniques" OR "learning techniques" OR "teaching strategies" OR "instructional strategies") AND education

Table II: The Selection Criterion is Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2014–2024	< 2014
Literature type	Journal (Article)	Conference, Book, Review

Table III: The Quality Appraisal

		Yes Expert			No Expert			Total agreement	Comments
		1	2	3	1	2	3	(%)	
Section A: Are the results valid?	1. Was there a clear statement of the aims of the research?	/	/	/				100	Excellent
	2. Is a qualitative, quantitative and mixed-method research approach appropriate?	/	/	/				100	Excellent
	3. Was the research design appropriate to address the aims of the research?	/	/	/				100	Excellent
	4. Was the recruitment strategy appropriate to the aims of the research?	/	/	/				100	Excellent
	5. Was the data collected in a way that addressed the research issue?	/	/	/				100	Excellent
Section B: What are the results	6. Was the data analysis sufficiently rigorous?	/	/	/				100	Excellent
	7. Is there a clear statement of findings?	/	/	/				100	Excellent
Section C: How valuable is the research?	8. How valuable is the research?	/	/	/				100	Excellent

RESULTS

Table IV outlines how the authors thoroughly analyzed 26 publications to extract assertions or information pertinent to the study's focus and Figure 1 shows a PRISMA flowchart detailing the search and selection processes.

This systematic review synthesized evidence from 26 eligible studies examining the integration of augmented reality (AR) in educational contexts. The results were organized according to three main themes: (i) the impact of AR on learning outcomes and motivation, (ii) instructional approaches for effective AR implementation, and (iii) challenges and limitations influencing AR adoption.

Impact of AR on Learning Outcomes and Motivation

Across the included studies, AR was consistently found to improve students' academic performance, conceptual understanding, and overall engagement. Several investigations reported that AR-based instruction led to higher post-test scores and improved retention compared to conventional methods. [8,9,13,18,19,23,26,30] These effects were particularly evident in science, medical, and engineering subjects that require spatial reasoning and visualization. The interactive manipulation of virtual models allowed learners to grasp abstract or dynamic phenomena more effectively than when using static resources.

In addition to cognitive benefits, motivation and attention levels were positively influenced. Multiple studies highlighted that learners exposed to AR activities displayed stronger curiosity, emotional involvement, and satisfaction during lessons. [9,11,13,18,20,25] The immersive and hedonic qualities of AR promoted intrinsic motivation by increasing enjoyment and reducing boredom. Learners reported feeling more confident and focused, suggesting that the technology supports sustained participation.

Collectively, the results indicate that AR enhances both cognitive and affective learning domains. When aligned with learning objectives, AR stimulates interest, maintains concentration, and supports meaningful knowledge construction through active engagement.

Table IV: Summary of Selected Article

No	Authors	Title	Journal	Findings
1	Huang et al.[8]	Animating eco-education: To see, feel, and discover in an augmented reality-based experiential learning environment	Computers & Education (2016)	- AR system improved learners' emotional engagement and learning effectiveness compared to traditional methods - increased curiosity and interest
2	Chiang et al.[9]	An Augmented Reality-based Mobile Learning System to Improve Students' Learning Achievements and Motivations in Natural Science Inquiry Activities	Educational Technology & Society (2014)	- augmented reality-based mobile learning system significantly improved students' learning achievements in inquiry-based activities - higher motivation levels in attention, confidence, and relevance dimensions - enhancing learning performance by reducing cognitive load
3	Cai et al.[10]	Tablet-based AR technology: Impacts on students' conceptions and approaches to learning mathematics according to their self-efficacy	British Journal of Educational Technology (2019)	- enhance students' conceptions and learning approaches - enhance learning experiences, particularly for students with higher self-efficacy, by fostering deeper understanding and engagement
4	Hsieh[11]	Development and Application of an Augmented Reality Oyster Learning System for Primary Marine Education	Electronics (2021)	- improved students' learning achievements - increased interest and motivation in learning - more engaging and interactive learning experience
5	Hsu[12]	Learning English with Augmented Reality: Do learning styles matter?	Computers & Education (2017)	- self-directed and task-based Augmented Reality (AR) educational game systems resulted in similar high learning effectiveness
6	Czok et al.[13]	Learning Effects of Augmented Reality and Game-Based Learning for Science Teaching in Higher Education in the Context of Education for Sustainable Development	Sustainability (2023)	- enhances motivation and user engagement - AR does not negatively affect knowledge acquisition compared to traditional learning environments
7	Kamal and Junaini[14]	The Effects of Design-Based Learning in Teaching Augmented Reality for Pre-University Students in The ICT Competency Course	International Journal of Scientific & Technology Research (2019)	- design-based learning (DBL) approach significantly enhances students' academic performance - increase in both lower-order thinking skills (LOTS) and higher-order thinking skills (HOTS) after the implementation of DBL
8	Nasir and Fakhruddin[5]	Design and Analysis of Multimedia Mobile Learning Based on Augmented Reality to Improve Achievement in Physics Learning	International Journal of Information and Education Technology (2023)	- multimedia mobile learning based on Augmented Reality (AR) significantly improves students' achievement
9	Chiang et al.[16]	Students' online interactive patterns in augmented reality-based inquiry activities	Computers & Education (2014)	- AR-based inquiry learning activity significantly increased student interactions for knowledge construction - immersive learning experiences, enhancing students' concentration and enabling them to achieve high-level thinking
10	Wen et al.[17]	Integrating augmented reality into inquiry-based learning approach in primary science classrooms	Education Tech Research Dev (2023)	- emphasize the importance of providing autonomy in learning and encouraging diverse knowledge representation to enhance creative thinking
11	Cercenelli et al.[18]	AEducaAR, Anatomical Education in Augmented Reality: A Pilot Experience of an Innovative Educational Tool Combining AR Technology and 3D Printing	International Journal of Environmental Research and Public Health (2022)	- enhance learning, motivation, and confidence with future medical technologies

Table IV: Summary of Selected Article

No	Authors	Title	Journal	Findings
12	Rodríguez-Abad et al.[19]	Online (versus face-to-face) augmented reality experience on nursing students' leg ulcer competency: Two quasi-experimental studies	Nurse Education in Practice (2023)	- (AR)-based online educational experience significantly improved academic performance - High scores were reported in motivation, satisfaction, and other learning determinants, indicating that AR enhances the teaching-learning process
13	Li et al.[20]	From motivational experience to creative writing: A motivational AR-based learning approach to promoting Chinese writing performance and positive writing behaviours	Computers & Education (2023)	- motivational AR-based (MAR) learning approach significantly improved students' performance - greater immersion and interaction
14	Lin et al.[21]	Mitigating the Urban-rural Digital Divide: A Dual Scaffolding-embedded Mobile Augmented Reality Learning Approach in the Post-COVID-19 Pandemic	Educational Technology & Society (2023)	- dual scaffolding-embedded mobile AR learning approach significantly improved learning achievement, higher-order cognition, and self-efficacy
15	Lee and Hsu[22]	Sustainable Education Using Augmented Reality in Vocational Certification Courses	Sustainability (2021)	- AR learning approach significantly improved students' learning effectiveness - reduced cognitive load for both active and reflective learners, making the learning process less burdensome
16	Küçük et al.[23]	Learning Anatomy via Mobile Augmented Reality: Effects on Achievement and Cognitive Load	Anatomical Sciences Education (2016)	- using mobile augmented reality (mAR) applications for learning anatomy achieved higher academic success - mAR applications effectively reduced the mental effort required to learn complex anatomical structures
17	Rizki et al.[24]	Cooperative model, digital game, and augmented reality-based learning to enhance students' critical thinking skills and learning motivation	Journal of Pedagogical Research (2024)	- Cooperative Model, Digital Game, and Augmented Reality (CAP)-based learning approach showed a significant improvement, achieving a high level of critical thinking skills
18	Harncharnchai and Saeheaw[25]	Context-aware learning using augmented reality and WebQuest to improve students' learning outcomes in history	Int. J. Innovation and Learning (2018)	- improved learning outcomes - expressed high satisfaction with the use of AR and WebQuest, enhancing their engagement and motivation in learning
19	Weng et al.[26]	Can an augmented reality-integrated gamification approach enhance vocational high school students' learning outcomes and motivation in an electronics course?	Education and Information Technologies (2024)	- AR-integrated gamification approach significantly improved students' learning outcomes across all domains (cognitive, affective, and psychomotor)
20	Cascales-Martínez et al.[27]	Using an Augmented Reality Enhanced Tabletop System to Promote Learning of Mathematics: A Case Study with Students with Special Educational Needs	EURASIA Journal of Mathematics Science and Technology Education (2017)	- increase in knowledge among students with learning disabilities, learning disorders, and attention deficit hyperactivity disorder - improved student motivation and collaboration during the learning process
21	Hsu[28]	Effects of gender and different augmented reality learning systems on English vocabulary learning of elementary school students	Univ Access Inf Soc (2019)	- Collective Game-Based (CGB) and Sequential-Mission Gaming (SMG) systems resulted in high learning effectiveness with no significant gender differences in performance
22	Cheng et al.[29]	An in-depth analysis of the interaction transitions in a collaborative Augmented Reality-based mathematic game	Interactive Learning Environments (2019)	- interaction transitions in a digital game-based learning environment are dynamic and non-linear
23	Ruiz-Ariza et al.[30]	Effect of augmented reality game Pokemon GO on cognitive performance and emotional intelligence in adolescent young	Computers & Education (2018)	- significant improvements in selective attention, concentration, and sociability - no significant improvements were observed in memory, mathematical calculation, or linguistic reasoning

Table IV: Summary of Selected Article

No	Authors	Title	Journal	Findings
24	Bos et al. [31]	Educational Technology and Its Contributions in Students' Focus and Attention Regarding Augmented Reality Environments and the Use of Sensors	Journal of Educational Computing Research (2019)	- increased student attention compared to traditional educational technologies like the Moodle virtual learning environment (VLE) - higher concentration level while interacting with the AR application
25	Giancaspro et al. [32]	An active learning approach to teach distributed forces using augmented reality with guided inquiry	Computer Applications in Engineering Education (2024)	- augmented reality (AR) as a guided instructional tool significantly improved students' understanding of distributed forces - AR technology also helped address misconceptions
26	Chen et al. [33]	Supporting informal science learning with metacognitive scaffolding and augmented reality: effects on science knowledge, intrinsic motivation, and cognitive load	Research in Science & Technological Education (2023)	- combination of metacognitive scaffolding and augmented reality (AR) significantly improved the science knowledge post-test scores - No significant differences were observed in cognitive load

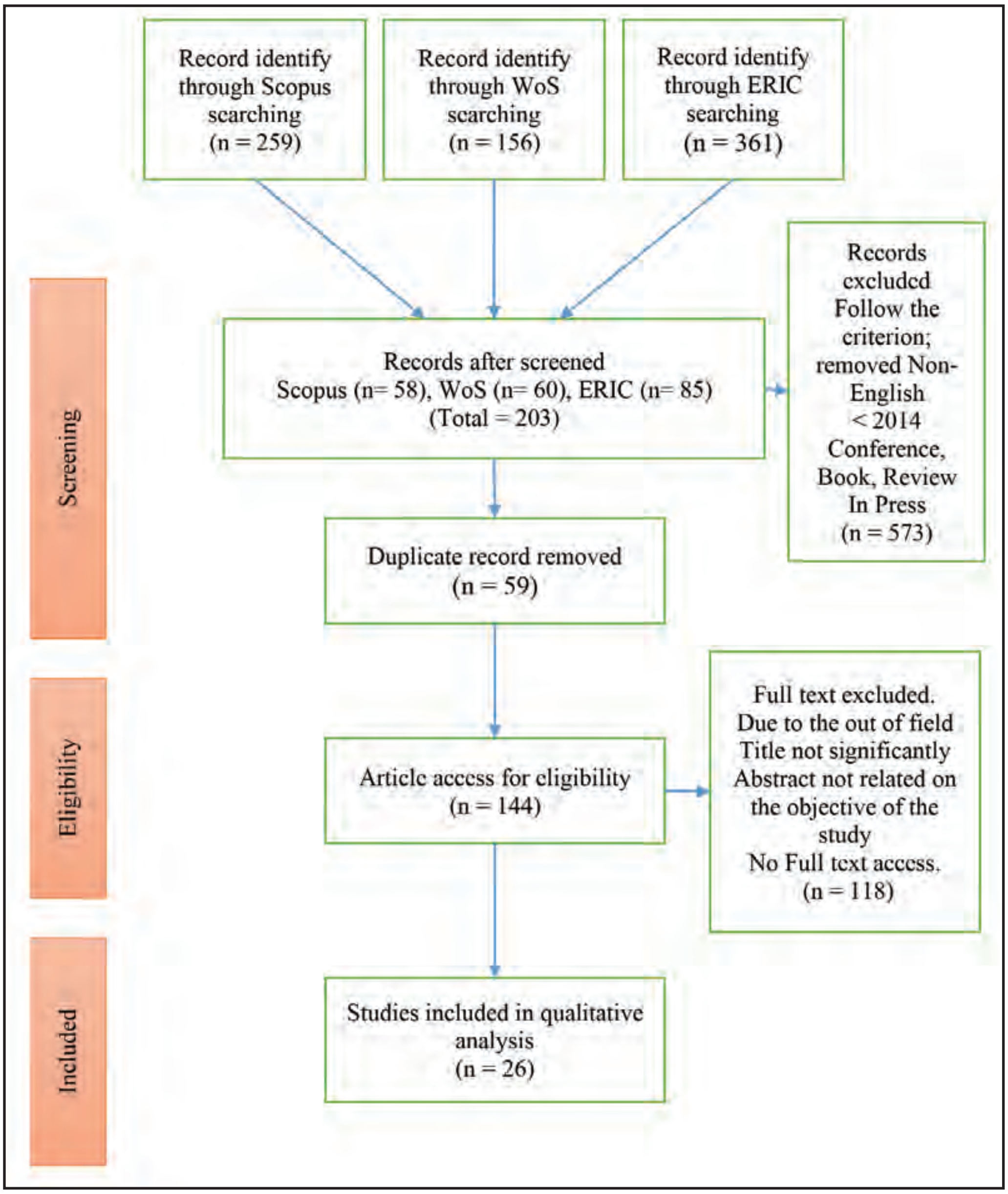

Fig. 1: Flow Diagram of the Proposed Searching Study [34]

Instructional Approaches for Effective AR Implementation

The majority of studies emphasized that AR's educational effectiveness depends greatly on the instructional framework used to deliver it. Inquiry-based learning emerged as a dominant approach, with several studies reporting improvements in students' scientific inquiry skills, problem-solving ability, and higher-order thinking when AR was integrated within structured investigations. [9,16,17,21,24,32] These designs encouraged exploration and hypothesis testing, allowing students to connect virtual observations with real-world phenomena.

Another recurring theme was the application of collaborative and game-based learning. Studies that combined AR with teamwork or gamified activities found that learners were more engaged, communicative, and cooperative in achieving shared objectives. [14,19,27,29] Collaborative AR environments fostered peer interaction and social learning, which contributed to greater conceptual understanding and skill development.

Additionally, a number of studies incorporated systematic design models such as ADDIE and design-based learning (DBL) to guide the creation and evaluation of AR modules. [15,17,22,28,30] The sequential phases of analysis, design, development, implementation, and evaluation ensured instructional alignment and minimized extraneous cognitive load. When AR content followed these structured processes, students demonstrated better comprehension, creativity, and application of learned concepts.

Overall, the reviewed studies suggest that AR integrated within structured instructional models—particularly inquiry-based, collaborative, and design-model approaches—produces more durable learning gains by aligning technological affordances with sound pedagogical principles.

Challenges and Limitations of AR in Education

Despite its promising outcomes, the reviewed evidence also revealed several limitations that constrain widespread AR implementation. Technical barriers such as limited device availability, unstable internet connectivity, and insufficient institutional support were frequently cited. [15,21,26,31] These issues reduced accessibility and created disparities between schools with different resource capacities.

Pedagogical challenges were also evident. Some studies warned that poorly aligned or overly complex AR content could overwhelm learners, leading to cognitive overload and confusion about learning objectives. [15,18,23,27] The absence of appropriate scaffolding or integration with curriculum goals diminished the educational value of AR activities.

Finally, social and contextual constraints emerged as critical barriers. Teacher readiness and professional development remained inadequate, and some educators expressed uncertainty or reluctance to adopt emerging technologies.[21,24,30] Cultural factors and accessibility concerns, particularly for students with disabilities or in under-resourced regions, further limited equitable use of AR.

In summary, the main constraints identified were technological limitations, instructional misalignment, and insufficient teacher preparedness. Addressing these issues through improved training, infrastructure, and inclusive design will be essential to optimize the pedagogical potential of AR in education.

In summary, evidence from studies 24–49 demonstrates that AR can significantly enhance learning outcomes, engagement, and motivation when embedded within well-structured pedagogical frameworks. However, its effectiveness depends on the availability of resources, the quality of instructional design, and the readiness of educators to implement it. Overcoming technical and contextual barriers remains critical to realizing the full educational potential of AR across disciplines.

DISCUSSION

This systematic review synthesized evidence from 26 studies examining the use of augmented reality (AR) within instructional frameworks. Overall, the findings indicate that AR-enhanced learning approaches are associated with improved learning outcomes, stronger learner engagement, and higher motivation. These results are consistent across a wide range of subjects, though the impact appears particularly significant in the sciences and health professions, where visual-spatial reasoning and procedural understanding are crucial. Prominent pedagogical strategies identified include inquiry-based, collaborative, and design-model-based learning approaches. The variation in study quality, design, and learner population, however, suggests that these outcomes should be interpreted with care. [35,36]

In medical and health-science education, the benefits of AR integration are clearly evident. AR has been applied successfully in teaching anatomy, clinical skills, and radiology, where complex spatial and procedural content often limits traditional instruction. Platforms such as AEducaAR, which combine 3D printing with AR, have been shown to enhance anatomical comprehension, motivation, and learner confidence among medical students. [18] Similarly, AR-based nursing and radiology modules have improved procedural performance and satisfaction, while reducing the cognitive strain associated with interpreting static two-dimensional materials. [37] By overlaying dynamic 3D anatomical structures onto real-world references, AR helps learners visualise spatial relationships that are otherwise difficult to grasp, thereby supporting both cognitive and psychomotor learning. [38]

When embedded within structured instructional models, AR appears to promote more meaningful and sustained learning. Inquiry-based frameworks encourage students to explore, test, and construct knowledge through guided discovery, whereas collaborative and game-based approaches create active learning environments that foster teamwork and communication. The ADDIE model offers a systematic process—analysis, design, development, implementation, and evaluation—that ensures AR activities remain aligned with learning outcomes and reduce unnecessary cognitive load.[39,40] Through such structured integration, AR can bridge the gap between theoretical knowledge and practical application, helping students connect classroom instruction to real-world clinical contexts.[41]

Despite its advantages, several limitations remain. Technical issues such as high hardware costs, unstable connectivity, and the limited availability of technical support continue to hinder implementation, particularly in low-resource or rural settings. [39] Pedagogical challenges also persist, as poorly aligned AR content can overwhelm learners and dilute intended learning objectives. Furthermore, educators often report insufficient training and support to incorporate AR effectively into their courses. Socio-cultural barriers—including resistance to new technologies and limited accessibility for students with disabilities—further restrict widespread adoption. [42,43]

Addressing these limitations requires a balanced approach that combines infrastructure investment with thoughtful instructional design and inclusive practice. Educators need ongoing professional development to ensure that AR integration is both purposeful and pedagogically sound. As AR continues to evolve, future research should examine its long-term effects on learning retention, clinical competence, and cost-effectiveness across different healthcare disciplines.

Review Strengths and Weaknesses

A key strength of this review lies in its methodological rigour and the breadth of educational settings examined. The systematic search strategy, which identified 26 peer-reviewed studies (references 8–33) from multiple databases, ensured that the evidence base was comprehensive and reflective of diverse instructional contexts. This methodological consistency enhanced the credibility of the synthesis and provided a balanced overview of AR integration across disciplines, including health sciences and STEM education.

However, the review was limited to peer-reviewed English-language publications and did not include grey literature, which may introduce a degree of reporting bias. The diversity of AR applications and instructional models also precluded a meta-analytic approach, as the data were too heterogeneous for quantitative synthesis.

CONCLUSION

Augmented reality (AR) holds strong transformative potential in education, particularly when carefully integrated with structured instructional approaches such as inquiry-based and collaborative learning. Its effectiveness depends on thoughtful instructional design, continuous educator support, and adequate infrastructure.

To fully realise this potential, technical, pedagogical, and social barriers must be addressed through coordinated institutional and policy efforts. Establishing standardised frameworks for AR implementation, ensuring inclusive access for diverse learners, and evaluating its long-term impact across educational settings are essential next steps. With these foundations, AR can evolve into a sustainable and equitable tool that fosters engagement, motivation, and deep learning across disciplines, especially in health sciences education.

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