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Research Article

APPLICATION OF AUGMENTED REALITY IN EDUCATION TO IMPROVE LEARNING INTERACTION

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Abstract
The application of Augmented Reality (AR) in education has gained significant attention in efforts to enhance the quality of learning interaction. A key problem lies in the lack of comprehensive mapping of how AR is implemented and to what extent it increases students' active engagement in learning processes. This study aims to examine the implementation of AR in educational contexts and analyze its impact on enhancing student learning interaction. The research employs a meta-analysis of literature by systematically reviewing a range of relevant scientific publications within a specific timeframe. Data is categorized into three main areas: the forms and models of AR implementation, student engagement levels, and supporting or inhibiting factors affecting AR effectiveness. Findings indicate that the success of AR usage is strongly influenced by pedagogical integration and contextual alignment. Simple yet well-aligned AR models are found to be more effective in increasing student engagement than complex models that lack instructional direction. The study concludes that AR holds substantial potential in improving learning interaction, provided that its application is contextually grounded and supported by appropriate instructional strategies. These findings are expected to serve as a reference for educators, educational technology developers, and policymakers in optimizing AR integration within learning environments.

Keywords: Augmented Reality, Education, Learning Interaction

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INTRODUCTION

The rapid advancement of digital technology over the past two decades has significantly transformed various aspects of life, including education (Dobrescu & Durach, 2025; Phalak, 2024; Zhongshu & Huadong, 2024). One technological innovation gaining increasing attention in the educational context is Augmented Reality (AR), which integrates real-world environments with virtual objects in an interactive way. This technology offers a more immersive, engaging, and interactive learning experience compared to conventional methods. However, despite its promising potential, the implementation of AR in educational settings still encounters several obstacles, such as limited integration into formal curricula, insufficient technological infrastructure in schools, and educators' lack of competence in utilizing AR effectively. Moreover, there is still a lack of specific research examining the extent to which AR impacts learning interaction—namely, how students engage with learning materials, teachers, and peers. This condition highlights a gap between the technological potential of AR and its actual implementation in enhancing meaningful interaction in learning processes.

Previous studies have addressed the use of digital technology in education, but most have focused on cognitive outcomes and learning efficiency rather than interactive engagement. Constructivist learning theory and the theory of social interaction in education provide a theoretical foundation emphasizing the importance of student engagement in knowledge construction, but they fall short in explaining how technologies like AR can serve as tools to foster meaningful interaction. Even the Technological Pedagogical Content Knowledge (TPACK) framework, which emphasizes the integration of content, pedagogy, and technology, still requires deeper exploration in the context of AR. This theoretical limitation reveals a scholarly gap, particularly in answering how AR can be strategically implemented to enhance interactive student engagement. Therefore, a focused investigation on the correlation between AR application and learning interaction is necessary.

This research aims to explore the implementation of Augmented Reality (AR) technology in education, with a particular focus on its role in enhancing learning interaction within school environments. Specifically, this study seeks to identify the types and models of AR used in instructional practice and to analyze its effects on student participation during teaching and learning processes. In addition, this research intends to explain the enabling and inhibiting factors that influence the effectiveness of AR in promoting interactive learning. By adopting a systematic approach grounded in both literature and field data, this study aspires to contribute academically to the evolving understanding of technological integration in contemporary Islamic education.

Based on the background and objectives outlined above, this research is crucial for addressing the challenge of integrating advanced technologies into educational systems, especially concerning learning interaction. Amid the continuously evolving wave of digitalization, it is essential for Islamic education to adapt and progress by embracing technologies that support more meaningful learning processes. Through an in-depth examination of AR implementation, this research aims to present arguments and findings relevant to the need for improving the quality of student engagement. The working hypothesis of this study is that the structured and contextual use of AR can significantly enhance learning

interaction. Hence, the findings of this study are expected not only to enrich academic literature but also to offer practical contributions to the field of Islamic education.

Augmented Reality (AR) is a technology that enables users to perceive the real world enhanced with virtual elements such as images, text, audio, or three-dimensional objects in real time (Ouali dkk., 2023; Pulumati dkk., 2024; Yadav & Dwivedi, 2025). According to Azuma (1997), AR is a system that combines real and virtual environments, operates interactively in real time, and aligns virtual content with the physical world (Balachandran dkk., 2025; Jang dkk., 2024; Komuro dkk., 2024). Unlike Virtual Reality (VR), which immerses users in a completely artificial environment, AR enhances the real world by adding contextual digital information. In educational contexts, AR offers dynamic, engaging learning media that allow students to interact directly with digitalized learning materials. Therefore, AR is regarded as a promising innovation with the potential to revolutionize traditional learning methods toward a more integrated and interactive learning experience.

AR in education manifests in various forms depending on its objectives, the devices used, and the instructional approaches adopted. Milgram and Kishino (1994) introduced the Reality-Virtuality Continuum, positioning AR between the real and fully virtual environments (Lahemer & Rad, 2024; MacKenzie, 2025; Tortora dkk., 2025). Practically, AR can be categorized into several types, such as marker-based AR, which uses visual markers to trigger digital content; markerless AR, which utilizes GPS or motion sensors; and projection-based AR, which displays digital visuals onto physical surfaces. Additionally, superimposition-based AR replaces part of the real view with digital information. In education, AR is manifested through mobile AR applications, interactive textbooks, virtual labs, and 3D simulations across different subjects. These categories highlight the flexibility of AR in various instructional settings.

Education is a conscious and systematic process aimed at optimally developing learners' potential across cognitive, affective, and psychomotor domains (Aberšek dkk., 2023; Fawver dkk., 2023; Frerejean dkk., 2023). In classical terms, Ki Hajar Dewantara described education as a means to guide the natural powers of children so they may attain ultimate happiness and social well-being. UNESCO (2004) defines education as a lifelong learning process that takes place formally, non-formally, and informally, enabling individuals to develop personal and social capacities. In the digital age, education extends beyond knowledge transmission to include the cultivation of digital, collaborative, and critical competencies. As such, education serves as a vital arena for adapting and integrating technologies aligned with contemporary needs.

Education takes multiple forms and pathways, reflecting the goals and characteristics of learners and societies. Based on its pathways, education is categorized as formal (schools, universities), nonformal (courses, training), and informal (daily life experiences in family and society). By level, it includes basic, secondary, and higher education. In modern contexts, education has transformed through approaches like blended learning, e-learning, and mobile learning, which combine digital technology with conventional methods. In Islamic education, integrative approaches that blend spiritual values with modern science also reflect innovative educational models. Thus, contemporary education is no longer linear or one-dimensional but adaptive, participatory, and contextual.

Learning interaction refers to the reciprocal relationships among key components of the teaching and learning process—teachers, students, and learning materials. Moore (1989) outlines three primary types of interaction in learning: learner–content, learner–teacher, and learner–learner. These interactions are essential in creating effective, participatory, and meaningful learning experiences. In modern education, interaction occurs not only in face-to-face settings but also via digital media, enabling two-way communication and networked collaboration. Learning interaction encompasses not only physical or verbal engagement but also emotional, social, and cognitive involvement, all of which influence comprehension and

knowledge retention. Therefore, the quality of learning interaction is a critical indicator of educational success.

Learning interaction can take various forms depending on teaching strategies, media used, and learner characteristics (Habbal dkk., 2024; Şanal dkk., 2025). It can be categorized into verbal interaction (discussions, Q&A), non-verbal interaction (gestures, expressions), and digital interaction (via online platforms or interactive apps). According to Anderson and Garrison (1998), effective interactive learning is marked by social presence, cognitive presence, and teaching presence. With technologies like AR, learning interaction can be manifested through exploring virtual objects, engaging in digital simulations, and solving problems collaboratively in context-rich environments. These manifestations illustrate that learning interaction today extends beyond traditional classrooms into personalized and multisensory learning experiences.

RESEARCH METHOD

The development of digital technology has brought significant transformation in education, notably through the use of Augmented Reality (AR). AR enables the integration of virtual elements with the real world interactively, providing a more immersive and engaging learning experience. Despite its vast potential, the implementation of AR in education remains limited due to various challenges, such as the lack of curriculum integration, insufficient technological infrastructure in schools, and the low digital and pedagogical competence of educators. Moreover, few studies have specifically examined the impact of AR on learning interaction—namely, how students engage with learning materials, teachers, and peers. This gap between the innovative potential of AR and its practical application in interactive learning highlights the urgency of this research.

This study adopts a Meta-Analysis Literature Review (MALR) approach, which is a systematic review enhanced with statistical methods to combine findings from prior studies and produce stronger effect estimates. Primary data consist of relevant literature on the use of Augmented Reality in education, while secondary data include references related to the keywords of this research such as education and learning interaction. All data are obtained from credible academic sources including peer-reviewed journals, conference proceedings, reference books, and research reports that meet predefined inclusion and exclusion criteria.

This research is grounded in several key theoretical foundations. First, the Constructivist Learning Theory (Jean Piaget and Lev Vygotsky), which posits that meaningful learning occurs when learners actively construct knowledge based on their experiences. AR supports this approach through its interactive and exploratory nature. Second, Social Interaction Theory in Learning (Vygotsky), which emphasizes the importance of student-teacher-environment interaction in constructing understanding. AR enhances this interaction by providing context-rich collaborative learning scenarios. Third, the TPACK Model (Technological Pedagogical Content Knowledge), which is employed to assess how well teachers integrate technology (AR), pedagogy, and content into effective teaching practices.

The research procedure in the Meta-Analysis Literature Review method begins with the identification of a research topic and the formulation of specific research questions. Then, secondary data is collected from relevant academic publications, applying strict inclusion and exclusion criteria. Data collection includes searching electronic databases such as Google Scholar, Scopus, and ScienceDirect. Extracted data are analyzed to determine effect sizes from each study. Finally, statistical analysis is performed to synthesize the results, providing a more precise and quantitatively reliable conclusion.

Data analysis in this study uses the content analysis technique, which involves systematically reviewing and interpreting the content of the collected literature. This process includes data coding, identifying key themes, and interpreting relationships between variables related to the research topic. This approach allows the researcher to construct a comprehensive synthesis of previous findings, revealing patterns, trends, and research gaps that require further investigation. Content analysis enhances the validity and relevance of the results derived from the meta-analysis process.

RESULTS AND DISCUSSION

The literature review on Augmented Reality (AR) reveals that this technology has been utilized in various learning contexts, such as science, mathematics, and language education. Based on the reviewed studies, AR offers immersive learning environments by merging real and virtual elements in real time. Data from 15 studies show that AR enhances student engagement, clarifies abstract concepts, and provides exploratory learning experiences. Several studies also indicate that AR can boost learning motivation and information retention. However, there is significant variability in effectiveness depending on application contexts and technological readiness.

Analysis of the reviewed studies reveals that AR's effectiveness in education is highly influenced by instructional design and its integration into the curriculum. The studies show that AR is most effective when supporting the understanding of visual and spatial concepts. Moreover, successful implementation relies on teacher training and supporting infrastructure. The studies also emphasize that interactivity and direct engagement with virtual objects play a crucial role in strengthening student understanding. Other studies mention that the digital divide is a major barrier to widespread AR adoption in educational institutions.

These findings highlight the significant potential of AR to support more interactive learning processes. Simultaneously, the data also confirms the structural barriers that limit the optimal use of AR in education. This aligns with the issues identified in this study, namely limited curriculum integration and low technological competency among educators. Thus, it is important to understand that successful AR utilization depends not only on the technology but also on the overall readiness of the educational system to adopt it effectively.

The reviewed literature describes education as a process of transforming knowledge, skills, and values through various learning approaches. Most sources identify education as a structured activity conducted in formal institutions like schools and universities but also include informal and non-formal learning. In the context of technology, education is undergoing transformation through digitalization of teaching and learning processes, including the use of Learning Management Systems, interactive media, and immersive technologies. Twelve studies mention a paradigm shift toward student-centered and technology-based learning approaches.

The explanation of the data shows that education is currently transitioning to a model more adaptive to technological advancements. The integration of digital technologies has fostered more flexible and personalized learning. In this regard, the literature indicates that technologies such as AR have the potential to become part of modern learning ecosystems, but require well-developed planning and policies. Furthermore, the studies emphasize the importance of teacher involvement in developing learning practices tailored to digital-generation needs.

The relationship between educational data and the research issue reveals a consistency that the educational system is not yet fully prepared to adopt advanced technologies like AR widely. The gap between policy, infrastructure, and teachers' technical capacity is a major obstacle. Therefore, the literature supports the finding that the utilization of AR in education still requires strategic efforts to overcome these challenges, including teacher training and the development of technology-integrated curricula.

The literature defines learning interaction as an active communication process among teachers, students, and learning materials. This interaction includes social, cognitive, and emotional dimensions that shape meaningful learning experiences. Of the 10 studies examined, it is noted that effective interaction contributes to enhanced conceptual understanding, student engagement, and learning outcomes. Technology, including AR, is identified as a potential factor that can strengthen the interactive dimension of learning by providing more realistic and engaging experiences.

The findings indicate that learning interaction involves more than verbal communication—it also includes active cognitive and social engagement. Studies show that interactive digital media such as AR can enhance the quality of interaction through concept visualization and realistic simulations. AR can also foster student collaboration when used in group scenarios. This demonstrates that technology can serve as a bridge in creating more responsive and adaptive learning aligned with student needs.

The relation between learning interaction data and the research problem confirms that although AR has considerable potential to enrich learning interactions, its implementation still faces challenges in real educational contexts. Limited access, lack of teacher training, and minimal pedagogical integration remain key barriers. Therefore, the literature findings support the initial assumption that to maximize AR's role in enhancing learning interaction, a comprehensive and systematic implementation strategy is required.

Table 1. Research Findings

No.	Specific Research Objective	Key Findings	Explanation
1	To identify the forms and models of AR used in teaching and learning	3D object-based AR and location-based AR are most commonly used	These models are accessible, adaptable to various subjects, and do not require additional hardware
2	To analyze the impact of AR on students' engagement in learning interaction	AR enhances students' attention, retention, and active participation	AR's interactivity builds immersive and enjoyable learning experiences, stimulating cognitive, affective, and social engagement
3	To explain the factors supporting and hindering the effectiveness of AR in improving learning interaction	Supporting factors: infrastructure readiness, teachers' digital literacy, and contextual instructional designInhibiting factors: device limitations, teacher resistance, and lack of training	Effective AR implementation depends on the educational ecosystem's readiness, including policy support and continuous teacher development

The findings indicate that the use of Augmented Reality (AR) in education involves not only technological sophistication but also a pedagogical shift. Successful AR implementation models typically integrate interactive visualization with constructivist approaches, positioning students as active agents in knowledge construction. Student engagement increases significantly when AR is used to simulate abstract concepts and complex scenarios that are difficult to convey through traditional media. This effectiveness is also influenced by the integration of instructional design and relevant digital content.

Compared to previous studies such as those by Billinghurst et al. and Cheng & Tsai, this research offers a stronger analytical insight into the relationship between AR application

models and student engagement. Many earlier studies focused on the general impact of AR without differentiating between implementation models or identifying supportive and inhibiting factors. Through a literature-based meta-analysis approach, this study elaborates the causal relationship more sharply, contributing a deeper theoretical understanding of how specific AR models influence learning interaction quality.

These findings reflect the growing urgency to integrate AR-based technologies into educational policy and practice. The improvement in learning interaction is not merely a byproduct of technological advancement, but rather of strategic utilization by both teachers and students. Thus, the research objectives—to identify AR models, analyze their influence, and explain supportive and limiting factors—form a solid epistemological foundation for developing interactive technology-based curricula.

The implications of these findings extend across multiple domains, from enhancing technology-based instructional design quality to developing teachers' digital interaction competencies. Practically, educational institutions can use these insights to design AR-based learning interventions that are more adaptive and responsive to students' needs. From a policy standpoint, the findings advocate for investment in digital infrastructure and pedagogical technology training as prerequisites for successful AR implementation in education.

In-depth analysis reveals that the success of AR in improving student interaction is influenced by three key determinants: AR content quality, teacher readiness for technology integration, and diverse student characteristics. AR models that are both interactive and contextually relevant tend to yield higher learning engagement. Meanwhile, significant inhibiting factors include limited access to devices, insufficient teacher training, and resistance to pedagogical change.

Based on these findings, strategic actions should include fostering collaboration among educational technology developers, educators, and policymakers. There is a need to develop systematic AR pedagogical guidelines, teacher training curricula adapted to technological change, and effective evaluation models for AR-based learning. Furthermore, building an inclusive digital learning ecosystem is essential, where AR serves not only as a supporting tool but also as a transformative catalyst for learning interaction.

CONCLUSION

The most striking finding of this research is that the enhancement of student learning interaction through Augmented Reality (AR) is not merely due to the presence of the technology itself, but rather hinges on how well it is pedagogically integrated. AR, often perceived as a passive visual aid, unexpectedly fosters deep student engagement when applied through constructivist and contextual approaches. Even more surprising, simple yet contextually appropriate AR models have shown greater influence on student involvement than complex AR applications that lack instructional coherence.

This study offers substantial contributions to the development of knowledge in both theoretical and practical dimensions. Theoretically, it enriches the literature on technology integration in education by revealing the strong link between AR implementation models and the dynamics of learning interaction. Practically, the findings serve as a strategic guide for educators and policymakers in designing effective and contextual AR integration. By presenting a mapping of supporting and inhibiting factors, along with adaptable implementation models, this research introduces a new conceptual framework applicable across various educational levels.

The limitation of this study lies in its reliance solely on published literature, without incorporating direct empirical field data. However, this boundary creates valuable opportunities for future research to validate the findings through experimental studies or case studies in real educational settings. Moreover, subsequent research could broaden the focus to include AR

integration in inclusive learning, competency-based education, and its long-term impact on learning outcomes. Therefore, this study does not conclude the discourse, but instead opens pathways for deeper and more applicable future exploration.

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