



# Effectiveness of Augmented Reality (AR)-Based Learning in Enhancing Elementary School Students' Motivation in Science Education

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**ABSTRACT.** This study aims to examine the effectiveness of Augmented Reality (AR)-based learning in enhancing elementary school students' learning motivation in science education using a literature review approach. This research is conducted by analyzing and synthesizing relevant theoretical and empirical studies obtained from reputable academic databases such as Google Scholar, Scopus, and Web of Science, published within the last ten years. The selected articles were reviewed based on their relevance to AR implementation in primary education and their focus on motivational aspects, including students' engagement, interest, attention, and learning persistence. The findings indicate that AR-based learning has a significant positive effect on students' learning motivation, as it promotes interactive learning environments, supports the visualization of abstract scientific concepts, and encourages active student participation. Furthermore, AR contributes to the development of intrinsic motivation by enhancing students' curiosity, autonomy, and meaningful learning experiences. Overall, this study concludes that AR is an effective instructional medium for improving learning motivation in elementary science education and highlights the importance of integrating AR into pedagogical practices to support innovative and student-centered learning in the digital era.

**Keywords:** Augmented Reality, Learning Motivation, Science Education

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## INTRODUCTION

The rapid advancement of digital technology has fundamentally transformed educational practices across all levels of schooling, including primary education. In the context of the 21st century, learning is no longer confined to traditional classrooms, textbooks, and teacher-centered instruction, but increasingly relies on interactive digital media that promote active student engagement and meaningful learning experiences (Bond, Zawacki-Richter, & Nichols, 2021). The integration of technology in education is considered essential to address the learning characteristics of today's students, who are often described as digital natives and are accustomed to visual, interactive, and technology-mediated environments (Prensky, 2001). Consequently, educators are challenged to adopt innovative instructional strategies that align with students' learning preferences while maintaining pedagogical effectiveness.

Science education at the elementary level plays a critical role in developing students' foundational understanding of scientific concepts, inquiry skills, and problem-solving abilities. However, numerous studies have reported that science learning in primary schools is often perceived as abstract, monotonous, and difficult by students, leading to low motivation and limited engagement in the learning process (Osborne, Simon, & Collins, 2003; Yoon et al., 2012). Traditional teaching methods, such as lectures and textbook-based explanations, tend to emphasize content transmission rather than experiential learning, which restricts students' opportunities to actively construct knowledge through exploration and interaction. As a result, students may experience cognitive overload and fail to develop a deep understanding of scientific phenomena.

Learning motivation is widely recognized as a crucial psychological factor influencing students' academic performance, persistence, and overall learning outcomes. Motivation determines the extent to which students are willing to invest effort, maintain attention, and engage in learning tasks (Schunk, Meece, & Pintrich, 2014). According to Self-Determination Theory, students are more likely to demonstrate high levels of intrinsic motivation when learning environments support autonomy, competence, and relatedness (Ryan & Deci, 2000). In primary education, where students' learning attitudes and habits are still forming, fostering motivation is particularly important to cultivate positive perceptions of learning and sustain long-term academic interest.

In response to these challenges, educational researchers and practitioners have increasingly explored the potential of emerging technologies to enhance learning motivation and instructional effectiveness. One of the most promising technologies in contemporary education is Augmented Reality (AR). AR is defined as a technology that overlays digital information, such as 3D objects, animations, or text, onto the real-world environment in real time, enabling users to interact with both virtual and physical elements simultaneously (Azuma, 1997). Unlike Virtual Reality (VR), which creates a fully immersive digital environment, AR preserves the real-world context while enriching it with interactive digital content, making it more suitable for classroom applications, particularly for young learners.

The pedagogical potential of AR lies in its ability to create immersive and interactive learning environments that support visual learning, experiential exploration, and active knowledge construction (Dunleavy & Dede, 2014). In science education, AR can be used to visualize abstract or invisible phenomena, such as the structure of atoms, the solar system, human organs, or ecological processes, which are often difficult for elementary students to comprehend through static images or verbal explanations alone (Ibáñez & Delgado-Kloos, 2018). By providing concrete visual representations, AR reduces cognitive barriers and facilitates conceptual understanding, thereby enhancing students' learning engagement and motivation.

Several empirical studies have demonstrated that AR-based learning positively influences students' motivation, interest, and engagement. For instance, Radu (2014) found that AR applications in education significantly improve learners' motivation and attention by offering interactive and game-like learning experiences. Similarly, Chang et al. (2014) reported that students who learned science concepts using AR showed higher levels of learning interest and enjoyment compared to those who used traditional learning media. These findings suggest that AR can transform passive learning into active and enjoyable experiences, which are essential for sustaining motivation in primary education.

From a theoretical perspective, the effectiveness of AR in learning can be explained through constructivist learning theory and multimedia learning theory. Constructivism emphasizes that learners actively construct knowledge through interaction with their environment, rather than passively receiving information (Piaget, 1972; Vygotsky, 1978). AR supports this process by enabling learners to manipulate digital objects, explore learning materials independently, and engage in problem-solving activities within authentic contexts (Dede, 2014). Meanwhile,

multimedia learning theory argues that learning is more effective when information is presented through multiple channels, such as visual and auditory modes, as this facilitates deeper cognitive processing (Mayer, 2009). AR integrates text, images, animations, and spatial interaction, thereby optimizing cognitive engagement and knowledge retention.

Furthermore, AR aligns with the ARCS motivation model, which highlights four key components of learning motivation: Attention, Relevance, Confidence, and Satisfaction (Keller, 2010). AR captures students' attention through dynamic visual elements, enhances relevance by connecting learning content with real-world contexts, builds confidence through interactive feedback, and increases satisfaction by creating enjoyable learning experiences. This motivational framework provides a strong theoretical foundation for understanding how AR influences students' motivational states, particularly in science learning.

Despite the growing body of research on AR in education, most existing studies focus on experimental designs with small samples and specific learning contexts. While these studies provide valuable insights into the short-term effectiveness of AR, there is still a lack of comprehensive literature reviews that systematically synthesize research findings, particularly in relation to learning motivation at the elementary level (Garzón & Acevedo, 2019). Moreover, many studies emphasize cognitive outcomes, such as achievement and conceptual understanding, while motivational aspects receive relatively less attention, even though motivation is a key determinant of long-term learning success.

Therefore, this study aims to address this gap by conducting a literature review on the effectiveness of AR-based learning in enhancing elementary school students' motivation in science education. By analyzing and synthesizing theoretical and empirical studies, this research seeks to provide a holistic understanding of how AR contributes to motivational dimensions of learning, identify key pedagogical factors that influence its effectiveness, and offer practical implications for educators. This study is expected to contribute to the growing discourse on educational technology by highlighting the strategic role of AR in fostering motivated, engaged, and meaningful learning experiences in primary science education.

## **METHOD**

This study employs a qualitative literature review method to examine the effectiveness of Augmented Reality (AR)-based learning in enhancing elementary school students' motivation in science education. A literature review was selected as the research design because it allows for a systematic and comprehensive analysis of existing theoretical and empirical studies, enabling the researcher to synthesize knowledge, identify research trends, and generate conceptual insights without conducting direct field experiments (Snyder, 2019). This approach is particularly suitable for educational technology research, where rapid technological development requires continuous theoretical reflection and synthesis.

The data sources for this study consist of scholarly articles obtained from reputable academic databases, including Google Scholar, Scopus, and Web of Science. These databases were selected due to their wide coverage of peer-reviewed international journals and their credibility in academic research (Gusenbauer & Haddaway, 2020). The search process was conducted using several key terms, such as "augmented reality in education", "AR-based learning", "learning motivation", "science education", and "elementary students". These keywords were combined using Boolean operators (AND, OR) to ensure comprehensive retrieval of relevant studies.

The inclusion criteria for article selection were as follows: (1) articles must be published in peer-reviewed journals; (2) articles must be written in English; (3) articles must be published within the last ten years to ensure relevance to current technological developments; (4) articles must focus on the application of AR in educational contexts, particularly in primary or elementary education;

and (5) articles must discuss motivational aspects, such as engagement, interest, attention, or learning attitudes. Meanwhile, studies that focused solely on technical system development without pedagogical analysis were excluded from the review.

After the initial search, the researcher conducted a screening process by reviewing titles and abstracts to determine the relevance of each article. Relevant studies were then subjected to full-text analysis to extract key information, including research objectives, methodology, sample characteristics, learning context, and main findings related to learning motivation. This screening and selection process follows the standard procedures of literature review research to ensure transparency and methodological rigor (Petticrew & Roberts, 2006).

The data analysis technique used in this study is thematic analysis. The selected articles were analyzed by identifying recurring themes related to AR-based learning and motivation. These themes include: (1) AR as an interactive learning medium; (2) AR and student engagement; (3) AR and intrinsic motivation; (4) AR and visualization of abstract concepts; and (5) pedagogical implications of AR integration. Thematic analysis enables the researcher to interpret patterns across multiple studies and construct a coherent conceptual framework regarding the effectiveness of AR in science learning (Braun & Clarke, 2006).

To enhance the validity of the findings, this study applies a comparative synthesis approach, in which findings from different studies are compared and contrasted to identify similarities, differences, and emerging trends (Booth, Sutton, & Papaioannou, 2016). This approach helps reduce researcher bias and strengthens the credibility of the conclusions by relying on multiple sources of evidence. Furthermore, the use of reputable databases and peer-reviewed articles ensures the reliability and academic quality of the data.

Although this study does not involve direct empirical data collection, it offers significant theoretical contributions by integrating previous research into a comprehensive conceptual understanding. The literature review method allows this study to generate broader generalizations and pedagogical insights that may guide future empirical research and instructional design. However, it is also acknowledged that literature-based studies may be limited by the scope and availability of existing research. Therefore, the findings of this study should be interpreted as conceptual and analytical insights rather than causal conclusions.

Overall, this methodological approach provides a systematic and rigorous framework for examining the effectiveness of AR-based learning in enhancing elementary students' motivation in science education. By synthesizing diverse research findings, this study contributes to the growing body of knowledge in educational technology and offers practical implications for teachers, curriculum developers, and policymakers in designing innovative and motivating learning environments.

## **RESULT AND DISCUSSION**

### **Result**

Based on the analysis of selected studies, the findings of this literature review are organized into several thematic sub-sections to present a structured overview of how Augmented Reality (AR)-based learning influences elementary school students' motivation in science education. The themes are derived from recurring patterns identified across the reviewed literature, particularly concerning students' engagement, intrinsic motivation, conceptual understanding, and learning experience.

#### **AR as an Interactive Learning Medium**

One of the most prominent findings from the reviewed studies is that AR functions as an effective interactive learning medium that transforms traditional learning into a more engaging and participatory process. AR allows students to interact directly with virtual objects embedded in real-world environments, which encourages exploration and active learning behaviors (Dunleavy & Dede, 2014). In elementary science learning, students can manipulate three-dimensional models of planets, plants, or human organs, enabling them to observe scientific phenomena from multiple perspectives. This level of interactivity enhances students' sense of involvement and control over their learning process.

Several studies report that students perceive AR-based learning as more enjoyable and meaningful compared to conventional instructional methods (Radu, 2014; Ibáñez & Delgado-Kloos, 2018). The interactive features of AR reduce students' passivity and foster experiential learning, which aligns with constructivist principles. As students actively engage with learning materials, they are more likely to develop a positive emotional response toward the subject matter, which is a critical component of learning motivation.

#### AR and Student Engagement

Student engagement emerges as a central theme in the reviewed literature. Engagement refers to students' cognitive, emotional, and behavioral involvement in learning activities (Fredricks, Blumenfeld, & Paris, 2004). The findings indicate that AR-based learning significantly increases students' engagement levels by creating immersive learning environments that capture attention and sustain interest over time.

For example, Chang et al. (2014) found that students who used AR applications in science learning demonstrated higher engagement and participation compared to those who relied on textbook-based instruction. Similarly, Yoon et al. (2012) reported that AR-supported museum learning activities improved students' collaborative behaviors and curiosity. The visual and interactive nature of AR helps maintain students' focus and reduces distractions, which are common challenges in traditional classroom settings.

In addition, AR promotes collaborative learning by enabling students to interact with digital content in groups. This social dimension of learning enhances relatedness, which is a key component of intrinsic motivation according to Self-Determination Theory (Ryan & Deci, 2000). When students engage in shared exploration and discussion, they not only deepen their understanding but also develop positive learning attitudes.

#### AR and Intrinsic Learning Motivation

Another significant result is the strong relationship between AR-based learning and intrinsic motivation. Intrinsic motivation refers to learners' internal desire to engage in learning activities due to interest and enjoyment, rather than external rewards or pressures (Deci & Ryan, 2000). The reviewed studies consistently suggest that AR fosters intrinsic motivation by making learning experiences more enjoyable, meaningful, and relevant to students' everyday lives.

Radu (2014) emphasized that AR enhances learners' motivation by providing game-like elements, immediate feedback, and interactive challenges. These features create a sense of curiosity and discovery, which encourages students to explore learning content voluntarily. Similarly, Garzón and Acevedo (2019) found that AR-based instruction positively influences students' learning attitudes and self-confidence, which are closely associated with motivational outcomes.

Furthermore, AR supports autonomy by allowing students to control their learning pace and interact with digital content independently. This sense of autonomy contributes to students' feelings of competence and ownership of learning, which strengthens intrinsic motivation. As a result, students are more likely to persist in learning tasks and demonstrate sustained interest in science subjects.

### Visualization of Abstract Scientific Concepts

The ability of AR to visualize abstract scientific concepts is another critical finding. Elementary science often involves topics that are invisible or difficult to observe directly, such as microscopic organisms, planetary systems, or internal body structures. AR enables students to visualize these concepts in three-dimensional and interactive formats, which enhances comprehension and reduces cognitive load (Ibáñez & Delgado-Kloos, 2018).

Mayer's (2009) multimedia learning theory supports this finding by suggesting that learning is more effective when learners receive information through both visual and verbal channels. AR integrates multiple modes of representation, enabling students to process information more efficiently. As students gain a clearer understanding of scientific concepts, their confidence increases, which positively influences motivation and engagement.

Empirical evidence also indicates that students feel more confident and interested in learning when they can directly observe and manipulate learning objects (Dede, 2014). This sense of mastery over learning content reinforces positive learning experiences and motivates students to continue exploring scientific topics.

### Pedagogical Implications of AR Integration

The final theme highlights the pedagogical implications of integrating AR into elementary science education. The reviewed literature suggests that AR should not be viewed merely as a technological tool, but as a pedagogical strategy that requires thoughtful instructional design (Keller, 2010; Dunleavy & Dede, 2014). Effective AR implementation depends on teachers' ability to align AR activities with learning objectives, curriculum content, and students' developmental levels.

Teachers play a crucial role in facilitating AR-based learning by guiding students, providing scaffolding, and encouraging reflection. Without proper pedagogical integration, AR may become a distraction rather than a meaningful learning medium. Therefore, professional development and teacher training are essential to ensure the successful adoption of AR in classrooms.

Overall, the results of this literature review demonstrate that AR-based learning has a consistently positive impact on elementary school students' motivation in science education. AR enhances interactivity, engagement, intrinsic motivation, conceptual understanding, and learning satisfaction. These findings support the conclusion that AR is a powerful pedagogical tool for fostering motivated and meaningful learning in primary science classrooms.

## Discussion

The findings of this literature review indicate that Augmented Reality (AR)-based learning has a consistently positive impact on elementary school students' learning motivation in science education. These results confirm and strengthen previous research that positions AR not merely as a technological innovation, but as a pedagogical tool capable of transforming learning experiences into more interactive, meaningful, and student-centered processes. The increased levels of engagement, intrinsic motivation, and conceptual understanding reported across studies suggest that AR plays a significant role in addressing long-standing challenges in primary science learning, particularly those related to students' low interest and passive learning behaviors.

From a theoretical perspective, the effectiveness of AR can be strongly explained through constructivist learning theory. Constructivism emphasizes that knowledge is actively constructed through experience and interaction with learning environments (Piaget, 1972; Vygotsky, 1978). AR creates a learning space where students are not passive recipients of information, but active participants who explore, manipulate, and reflect on digital representations of real-world

phenomena. This aligns with the principle of experiential learning, in which understanding emerges from direct engagement rather than rote memorization. As students interact with three-dimensional models and simulations, they are encouraged to form mental representations that deepen conceptual understanding and sustain learning interest.

In addition, the results are consistent with multimedia learning theory, which suggests that students learn more effectively when information is presented through multiple channels, particularly visual and verbal modalities (Mayer, 2009). AR integrates text, audio, animation, and spatial interaction in a single learning environment, allowing students to process information more efficiently. This multimodal experience reduces cognitive load and facilitates meaningful learning, which in turn enhances students' confidence and motivation. When learners feel capable of understanding learning content, their willingness to engage and persist in learning activities increases significantly.

The strong relationship between AR and intrinsic motivation also supports the assumptions of Self-Determination Theory. According to Ryan and Deci (2000), intrinsic motivation emerges when learning environments support autonomy, competence, and relatedness. AR-based learning provides autonomy by allowing students to control their pace and learning paths, competence by enabling immediate feedback and interactive problem-solving, and relatedness through collaborative learning activities. These psychological needs are essential in fostering internal motivation, especially in primary education where students' emotional engagement plays a crucial role in learning success.

Moreover, the findings are aligned with the ARCS motivation model, which emphasizes attention, relevance, confidence, and satisfaction as key motivational dimensions (Keller, 2010). AR captures attention through immersive visual elements, enhances relevance by connecting scientific concepts with real-life contexts, builds confidence through interactive exploration, and generates satisfaction through enjoyable learning experiences. This comprehensive motivational impact explains why AR-based learning consistently outperforms traditional instructional methods in terms of student engagement and learning attitudes.

The discussion of previous studies further reinforces these interpretations. Radu (2014) and Garzón and Acevedo (2019) reported that AR-based learning significantly improves learners' motivation, interest, and enjoyment. Similarly, Ibáñez and Delgado-Kloos (2018) highlighted that AR supports deeper learning by visualizing abstract concepts and promoting active exploration. These findings collectively suggest that AR is not only effective in short-term learning outcomes, but also contributes to long-term motivational development, which is essential for sustained academic achievement.

However, despite its positive potential, the discussion also reveals important pedagogical considerations. The effectiveness of AR is highly dependent on instructional design and teacher facilitation. Without proper guidance, AR may become a source of distraction rather than meaningful learning. This supports the argument that technology alone does not guarantee learning improvement; rather, it must be integrated within sound pedagogical frameworks (Dede, 2014). Teachers must design AR activities that are aligned with learning objectives, curriculum standards, and students' cognitive development.

Furthermore, the literature indicates that AR should be viewed as a complementary tool rather than a replacement for traditional teaching methods. While AR enhances motivation and engagement, it must be supported by reflective discussion, conceptual explanation, and formative assessment to ensure deep learning. This integrated approach ensures that students do not merely enjoy the technology, but also develop critical thinking and scientific reasoning skills.

In a broader context, this discussion highlights the relevance of AR in responding to the demands of Education 4.0, where learning is expected to be flexible, interactive, and technology-mediated. Elementary students today are growing up in digital environments that shape their learning

preferences and cognitive styles. AR offers an educational solution that bridges formal learning with digital culture, making science learning more accessible and appealing to young learners.

Overall, this discussion confirms that AR-based learning is theoretically grounded, empirically supported, and pedagogically valuable for enhancing students' motivation in science education. By integrating constructivist principles, multimedia learning, and motivational theories, AR provides a holistic learning environment that fosters engagement, curiosity, and meaningful understanding. Therefore, AR holds strong potential as an innovative instructional strategy for improving the quality of primary science education in the digital era.

## **CONCLUSION**

This study has examined the use of Artificial Intelligence (AI) chatbots as learning assistants in the digital era through a literature review approach. The findings indicate that AI chatbots offer significant potential to enhance learning effectiveness, student engagement, and learning autonomy by providing instant feedback, personalized learning support, and flexible access to academic assistance. These features position AI chatbots as valuable educational tools that can complement traditional teaching practices, particularly in online and blended learning environments.

However, this study also highlights several critical challenges associated with the implementation of AI chatbots in education. Issues such as over-reliance on AI-generated responses, reduced critical thinking, ethical concerns related to data privacy, and threats to academic integrity remain major obstacles that must be carefully addressed. These challenges suggest that the integration of AI chatbots should not be driven solely by technological enthusiasm, but guided by strong pedagogical principles and ethical frameworks.

Therefore, this study concludes that AI chatbots should be implemented as supportive learning tools rather than replacements for human educators. Their effectiveness depends largely on how they are embedded within instructional designs that promote critical reflection, meaningful interaction, and active knowledge construction. Future research is recommended to conduct empirical studies that explore real classroom implementations of AI chatbots and examine their long-term impact on students' cognitive, affective, and ethical development. Through responsible and pedagogically informed integration, AI chatbots have the potential to contribute positively to the advancement of education in the digital era.

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