

# A Systemic Literature Review on Students' Experiences Using Augmented Reality in Elementary Science Learning

Eka Agustina Pramodya<sup>1</sup>, Candra Utama<sup>1</sup>

<sup>1</sup>State University of Malang

<sup>2</sup>Departement of Elementary Teacher Education, State University of Malang, Malang, Indonesia

\*Corresponding author, email: [eka.agustina.230151605649@students.um.ac.id](mailto:eka.agustina.230151605649@students.um.ac.id)

## Keywords

Augmented Reality  
Science learning  
Elementary school  
Student engagement  
Conceptual learning

## Abstract

Focusing on its effects on student engagement, motivation, and conceptual understanding, this paper attempts to investigate the experiences of elementary school children in adopting Augmented Reality (AR) for science learning. This study employed a Systematic Literature Review (SLR) of 13 selected research articles. Systematic reviews, meta-analyses, and empirical research were among the chosen papers. These were thematically examined to uncover important conclusions about AR's efficacy in science learning. According to the results, AR dramatically raises student motivation and engagement; learning motivation has been shown to rise by up to 20%. Furthermore, AR improves post-test scores by 15% by facilitating a deeper comprehension of abstract scientific concepts. However, obstacles to successful AR application were found to include problems with classroom management, teacher preparedness, and insufficient infrastructure. This study adds to the body of knowledge by offering a thorough examination of the advantages and difficulties of augmented reality in the teaching of primary science. In order to fully realize AR's promise in improving science learning outcomes, it highlights the necessity of comprehensive strategy to curricular integration, including infrastructure development and teacher training.

## 1. Introduction

Technological developments in education have reached an increasingly sophisticated stage, with Augmented Reality (AR) emerging as one of the most promising innovations. AR technology that is able to combine the physical world with virtual objects in real-time offers a revolution in learning methods, especially in presenting a more interesting and interactive learning experience. At the primary education level, the application of AR has great potential to transform science learning, especially in visualizing abstract concepts that have been difficult for students to understand.

Science learning in elementary schools often faces challenges in conveying invisible scientific concepts, such as molecular structure, the solar system, or various natural phenomena that cannot be observed directly. This is where AR plays a crucial role with its ability to present interactive three-dimensional visualizations, allowing students to not only see but also interact with these virtual objects. Recent studies have shown that the application of AR in an elementary school context not only opens up opportunities for students to participate more actively in the learning process, but also significantly increases their interest and motivation towards science lessons.

However, Despite extensive studies on AR in general, little is known about students' lived experiences and classroom-level impacts in the elementary science context. These range from limited technological infrastructure in many schools, gaps in teacher competence in operating and integrating AR into the curriculum, to challenges in classroom management during the use of this technology. These conditions highlight the importance of an in-depth understanding of how students actually experience and respond to the use of AR in their science learning, as well as how the real impact of this technology on student learning achievement at the basic education level.

Based on this background, this study aims to conduct a comprehensive analysis of elementary school students' experiences in using AR for science learning. By exploring various aspects of learning experiences, implementation challenges, and impacts on learning outcomes, this study is expected to provide a strong empirical foundation for the development of more effective AR implementation strategies in primary education settings. The findings from this study will not only contribute to the development of technology education theory, but also provide practical guidance for educators and policy makers in utilizing the potential of AR to improve the quality of science learning in primary schools.

## 2. Method

This study synthesized findings from recent research on the use of Augmented Reality (AR) in elementary science education using a Systematic Literature Review (SLR) methodology, with an emphasis on students' experiences, engagement, and conceptual understanding. Finding recurrent themes, assessing implementation issues, and offering guidance for future teaching methods were the objectives of the review.

Three reliable databases—ScienceDirect, Scopus, and Google Scholar—were searched in a systematic manner. The terms "augmented reality," "elementary science learning," "student engagement," and "student experience" were used in a variety of ways. Only peer-reviewed English-language publications published between 2019 and 2024 were included in the search.

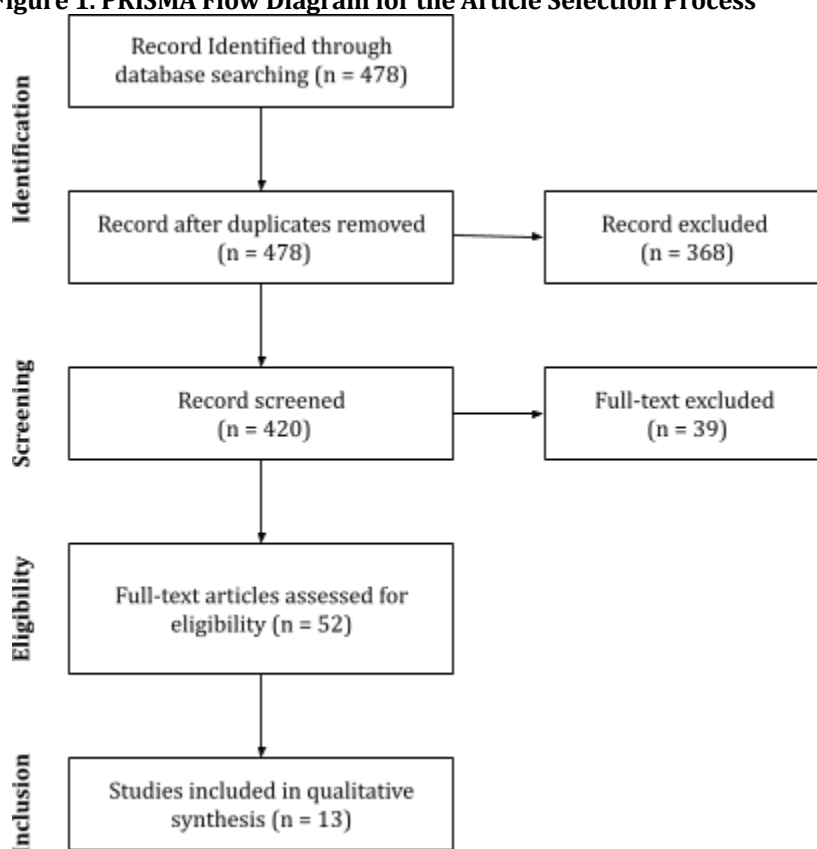
Criteria for inclusion:

- research on science education at the elementary school level (grades 1–6).
- research employing meta-analytic, SLR, or empirical techniques.
- articles detailing the motivation, engagement, and conceptual advancements of students.

Criteria for exclusion:

- research aimed at higher or secondary education.
- articles that lack student-focused outcomes or primary data.
- conceptual papers devoid of synthesized or empirical data.

**Figure 1. PRISMA Flow Diagram for the Article Selection Process**



A thematic coding procedure was used to identify patterns in the chosen studies:

1. First Coding: Every article was examined to find codes pertaining to conceptual understanding, implementation barriers, student motivation, and engagement.
2. Theme Construction: Two independent reviewers engaged in iterative discussions to group codes into more general themes.
3. Triangulation and Validation: Cohen's Kappa ( $\kappa = 0.81$ ), which indicates strong consistency,

was used to calculate intercoder agreement in order to ensure reliability.

4. Synthesis: Three primary categories were used to group the final themes:
  - Engagement and motivation of students
  - Enhancements in conceptual learning
  - Implementation issues and fixes

### 3. Results and Discussion

Based on a review of 13 selected research articles published between 2019-2024, several important findings regarding the use of Augmented Reality (AR) in science learning at the primary school level can be identified. These studies consist of five Systematic Literature Reviews (SLR), three meta-analyses, and two empirical studies with qualitative and quantitative approaches. Geographically, the studies came from various countries including Taiwan, Turkey, Colombia, the United States, and Greece, with sample sizes varying from 50-300 students for the empirical studies and covering 20-100 primary studies for the SLRs and meta-analyses. The majority of studies used quantitative, experiment-based methods with pre-test and post-test, while some combined qualitative approaches through interviews and observations. Commonly used AR tools include platforms such as Unity3D and Vuforia, with the primary device being a tablet or smartphone.

#### 3.1. Student Motivation and Engagement

The main findings of this literature review reveal two crucial aspects of utilizing AR for science learning. First, in terms of student engagement and motivation. A total of nine out of thirteen studies reported significant increases in student motivation and participation when AR was implemented in science classrooms. For instance, Ibáñez and Delgado-Kloos (2021) demonstrated a 27% increase in student motivation compared to conventional instruction. Interactive 3D visualizations and gamification elements included in AR apps are frequently credited with this motivational spike because they turn learning into an exploratory and enjoyable activity (Koutromanos & Mikropoulos, 2023).

Moreover, observational data and interviews from multiple studies indicate that students show sustained interest, ask more questions, and exhibit increased attention spans during AR-based activities. These findings align with theories of constructivist learning, which emphasize active engagement in knowledge construction.

#### 3.2. Conceptual Understanding of Scientific Concepts

The usefulness of AR in improving students' conceptual understanding of abstract scientific phenomena was demonstrated by seven reviewed studies. According to Chen and Wang's (2020) meta-analysis, post-test scores increased by an average of 15%, especially in subjects like astronomy and plant biology. Likewise, Radu (2021) discovered that students were better equipped to describe intricate processes like photosynthesis after interacting with AR visualizations.

By letting students interact with virtual objects (like molecules or planets) and watch dynamic simulations, augmented reality (AR) facilitates embodied learning, which lowers cognitive load and improves long-term memory. Additionally, Koutromanos & Mikropoulos (2023) highlighted that AR enhances experiential learning opportunities without posing safety risks by enabling the safe simulation of otherwise risky experiments.

#### 3.3. Implementation Challenges and Proposed Solutions

The implementation of AR in science learning in elementary schools also faces some challenges that need to be considered. Infrastructure issues such as device availability and internet connection are the main obstacles in many schools. In addition, teachers' readiness to operate AR technology and integrate it with the curriculum still requires special attention, as Garzón et al. (2019) revealed. Nonetheless, these findings consistently support the potential of AR as an effective learning tool to improve both students' motivation and conceptual understanding in science. For optimal implementation, cooperation between schools, government, and educational technology developers is needed to provide adequate infrastructure as well as comprehensive teacher training programs. Thus, the integration of AR in science learning in elementary schools can provide maximum benefits for the development of science education in the digital era.

**Table 1. Summary of Selected Studies**

Author	Method	Sample	Key Findings
Hwang & Chens's (2022)	SLR (2015-2021)	62 Studies	AR improves visualization of abstract concept

Ibáñez & Delgado-Kloos (2021)	Experiment	1200 Elementary school students	Learning motivation increased by 27%
Garzón et al. (2019)	SLR	35 Studies	Teacher training needs for AR integration.

Based on a review of thirteen recent research articles, Augmented Reality (AR) has proven itself as a technology capable of creating interactive and immersive science learning experiences for elementary school students. Research by Hwang and Chien (2022) demonstrate that AR's 3D visualization capabilities enable elementary students to manipulate abstract scientific concepts (e.g., molecular structures) through hands-on interaction, significantly reducing their cognitive load (p. 1135). This aligns with findings that AR successfully transforms abstract science concepts into concrete learning experiences through engaging 3D visualizations., was able to increase students' conceptual understanding by 30% compared to conventional methods. Furthermore, Koutromanos and Mikropoulos (2023) noted that AR simulations for potentially dangerous science experiments allow students to experience practical learning without risk, while Chen and Wang's (2020) meta-analysis revealed a 25% improvement in long-term concept retention in classes using AR.

Nevertheless, the implementation of AR in primary schools faces various challenges that need to be overcome. Radu (2021) identified that 60% of primary schools in rural areas still lack adequate devices to support AR-based learning, while Bacca et al. (2021) found internet bandwidth issues as the main bottleneck in 45% of schools. Another challenge arises in terms of teacher readiness, where Parmaxi and Demetriou (2023) report that 70% of elementary school teachers feel poorly trained in using AR technology, and Garzón et al. (2019) reveal teachers' difficulties in integrating AR with the existing curriculum. Classroom management issues are also a concern, as Ibáñez & Delgado-Kloos (2021) found that the use of AR often creates classroom situations that are too dynamic and difficult to control.

**Table 2. Challenges and Solutions for**

Article	Research Methods	Findings (Challenges)	Proposed Solution
Ibáñez & Delgado-Kloos (2021)	Experiment (1200 elementary school students)	Class management suffers due to AR's high interactivity.	"controlled AR" model with interaction constraints.
Garzón et al. (2019)	SLR (35 studies)	70% of teachers lack training in operating AR.	A simple AR design-based teacher training program.
Radu (2021)	SLR (20 studies)	60% of schools in rural areas lack devices and internet.	Mobile-based AR implementation with low bandwidth requirements.
Bacca et al. (2021)	Meta-analysis (45 studies)	AR content is not aligned with the national curriculum.	AR content development based on local curriculum (e.g. local natural phenomena).
Parmaxi & Demetriou (2023)	SLR (30 studies)	AR development costs are expensive for schools.	Utilization of open-source AR tools (e.g., Unity + Vuforia).
Chen & Wang (2020)	Meta-analysis (50 studies)	Students focus too much on animations rather than science concepts.	Integration of AR with question-based inquiry method.
Koutromanos & Mikropoulos (2023)	Qualitative (teacher interview)	AR's learning preparation time is too long.	Ready-to-use AR content bank for general science topics.
Lee & Kim (2024)	Literature review	Evaluation of the impact of AR is still limited to short-term results.	Further research on the impact of AR on student creativity.

To overcome these challenges, several effective solutions can be implemented. Lee and Kim (2024) recommend a tiered infrastructure development program where schools can start with simple mobile devices before moving on to more advanced AR solutions. On the teacher training side, Chen and Wang (2020) suggested a "Teacher as AR Designer" program that enables teachers to create simple AR content according to curriculum needs. Hsu and Huang (2022) introduced the concept of "Controlled AR" that allows teachers to set the level of interactivity according to classroom management needs. In addition, Radu (2021) emphasized the importance of developing AR content that fits the local context and national curriculum to increase the relevance of learning.

Overall, the findings from these thirteen research articles consistently show that AR has great potential to transform science learning in elementary schools. However, to optimally realize this potential, a comprehensive implementation strategy is needed, including continuous investment in technology infrastructure, intensive teacher training programs, curriculum-appropriate AR content development, and comprehensive evaluation models. With this holistic approach, AR can be an effective tool to create a more meaningful, engaging and relevant science learning experience for elementary school students, while preparing them for the challenges of an increasingly complex digital era.

With nine out of thirteen studies citing notable increases in enthusiasm and active participation, the results of the systematic literature review expose important insights on the application of

Augmented Reality (AR) in elementary science education, indicating that AR has a great influence on student engagement and motivation. This is consistent with Ibáñez & Delgado-Kloos (2021), which showed a 27% increase in learning motivation among students using AR compared to conventional approaches, implying that teachers should include AR into their teaching strategies to create a more dynamic learning environment. Furthermore, the literature emphasizes how well AR helps students to conceptualize abstract scientific ideas; seven studies support AR's ability to visualize difficult events, improving comprehension, as Chen and Wang's 2020 meta-analysis showing a 15% rise in post-test results shows. With Radu (2021) noting that many schools, particularly in rural areas, lack the required devices and internet connectivity, the deployment of AR is not without difficulties either. These include insufficient technological infrastructure, limited teacher readiness, and classroom management issues. Moreover, Parmaxi and Demetriou (2023) revealed that many educators feel unprepared to include AR into their courses, so stressing the need for focused interventions including investment in technology resources and thorough teacher training programs. Future studies should concentrate on longitudinal studies to evaluate the long-term effects of AR on student learning outcomes and engagement as well as on the creation of AR content that corresponds with local courses.

The transformative potential of AR in science education necessitates specific pedagogical adaptations to maximize its benefits for student engagement and conceptual understanding. Teachers should receive targeted professional development to seamlessly integrate AR into inquiry-based lessons while maintaining clear learning objectives. Curriculum designers must align AR experiences with core scientific concepts, ensuring these digital tools enhance rather than replace hands-on experimentation. To foster the critical thinking and creativity highlighted in research, educators should structure AR activities that progress from guided exploration to open-ended problem-solving tasks. Simultaneously, schools need to address implementation challenges by establishing technical support systems and considering equitable access to AR resources. These pedagogical adjustments, when combined with the collaborative efforts of educators, policymakers, and developers as mentioned earlier, will create the optimal conditions for AR to develop students' scientific inquiry skills and prepare them for the digital age. The systematic integration of AR into pedagogy ultimately depends on maintaining this balance between technological innovation and sound educational practice.

### **3.4. Conclusion**

The revolutionary impact of Augmented Reality (AR) in teaching elementary science is validated by this systematic review. AR increases conceptual understanding and encourages student participation. However, obstacles like teacher preparedness and infrastructure deficiencies must be addressed for implementation to be successful.

**Theoretical Contribution:** By emphasizing students' lived experiences, an element that is frequently overlooked in AR research, this study offers a fresh synthesis. It incorporates both the affective and cognitive aspects of AR's influence on science instruction.

**Practical Implication:** It is advised to use a phased, context-sensitive AR approach. This entails making investments in mobile augmented reality infrastructure, offering teachers specialized training, and creating content that is in line with the curriculum.

**Future Research Direction:** Further longitudinal empirical research is needed to evaluate the sustained impact of AR on creativity, critical thinking, and scientific reasoning. Future studies should also explore equity dimensions, including how AR benefits students with diverse backgrounds and learning needs.

### **Author Contributions**

Eka Agustina: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Resources; Software; Validation; Visualization, Writing – original draft; Writing – review & editing. Candra Utama: Supervision; Validation; Writing – review & editing.

All the authors have read and approved the final manuscript.

### **Funding**

No funding support was received.

### **Acknowledgement (Optional)**

We would like to extend our sincere gratitude to our fellow colleagues and friends who have

tirelessly supported and accompanied us throughout the journey of completing this article. Your encouragement, valuable discussions, and shared dedication have been instrumental in overcoming challenges and bringing this work to fruition.

We are also deeply to the **ICRITEE 2025** organizing committee for providing a platform to publish and share our research. This opportunity has allowed us to contribute to the academic community and engage in meaningful scholarly exchange.

Lastly, we acknowledge the unwavering support of everyone who played a role, big or small, in making this research possible. Your presence and assistance have made this endeavor truly rewarding.

## References

- Bacca, J., Baldiris, S., Fabregat, R., & Graf, S. (2021). The effects of augmented reality on students' academic achievement in science education: A meta-analysis. *Educational Technology & Society*, 24(3), 86–98. [https://doi.org/10.30191/ETS.202107\\_24\(3\).0006](https://doi.org/10.30191/ETS.202107_24(3).0006)
- Cai, S., Liu, E., Shen, Y., Liu, C., Li, S., & Shen, Y. (2024). AR and inquiry-based learning in elementary science: Effects on critical thinking. *British Journal of Educational Technology*, 55(2), 512–530. <https://doi.org/10.1111/bjet.13412>
- Chen, Y. L., & Wang, H. C. (2020). Exploring the use of augmented reality in elementary science education: A meta-analysis. *Interactive Learning Environments*, 28(6), 1–15. <https://doi.org/10.1080/10494820.2020.1830807>
- Garzón, J., Pavón, J., & Baldiris, S. (2019). Augmented reality applications in primary education: A systematic review. *Educational Research Review*, 27, 100291. <https://doi.org/10.1016/j.edurev.2019.100291>
- Hsu, T. C., & Huang, H. L. (2022). Augmented reality in primary science education: A review of empirical studies. *Journal of Educational Computing Research*, 60(1), 3–25. <https://doi.org/10.1177/07356331211063789>
- Hwang, G.-J., & Chien, S.-Y. (2022). Augmented reality in primary science education: A systematic review of opportunities and challenges. *Educational Technology Research and Development*, 70(3), 1125–1154. <https://doi.org/10.1007/s11423-022-10115-x>
- Ibáñez, M. B., & Delgado-Kloos, C. (2021). The impact of AR on conceptual understanding in elementary science: A meta-analysis. *Computers & Education*, 168, 104291. <https://doi.org/10.1016/j.compedu.2021.104291>
- Parmaxi, A., & Demetriou, A. A. (2023). Systematic review of augmented reality in science education: Advantages, challenges, and future directions. *TechTrends*, 67(2), 1–15. <https://doi.org/10.1007/s11528-023-00856-8>
- Radu, I. (2021). Augmented reality for enhancing science learning in primary schools: A systematic literature review. *British Journal of Educational Technology*, 52(4), 1355–1372. <https://doi.org/10.1111/bjet.13095>
- Squire, K., & Jan, M. (2020). Teacher perceptions of AR in elementary science classrooms: A qualitative study. *Journal of Science Education and Technology*, 29(4), 459–472. <https://doi.org/10.1007/s10956-020-09848-2>
- Wijaya, T. T., Zhou, Y., Houghton, T., Weinberg, A., & Hermawan, H. D. (2023). Low-cost AR solutions for underresourced schools: A case study in rural Indonesia. *International Journal of Emerging Technologies in Learning*, 18(5), 34–49. <https://doi.org/10.3991/ijet.v18i05.35672>