NUSRA: Jurnal Penelitian dan Ilmu Pendidikan
Volume 6, Issue 2, Mei 2025
DOI: https://doi.org/10.55681/nusra.v6i2.3592
Homepage: ejournal.nusantaraglobal.ac.id/index.php/nusra

p-ISSN: 2715-114X
e-ISSN: 2723-4649
pp. 259-266

AUGMENTED REALITY (AR)-BASED LEARNING INNOVATION TO IMPROVE STUDENT UNDERSTANDING SUBJECTS

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Article History

Received: 4 February 2025
Revised: 8 May 2025
Published: 21 May 2025

ABSTRACT

This study investigates the implementation of Augmented Reality (AR) technology as an innovative learning tool to enhance student understanding across various subjects. The integration of AR in educational settings has shown promising potential in creating interactive and immersive learning experiences. Through a systematic analysis of AR implementation in classroom settings, this research examines its effectiveness in improving student comprehension, engagement, and learning outcomes. The study employs a mixed-method approach, combining quantitative assessment of student performance with qualitative evaluation of learning experiences. Results indicate that AR-based learning significantly improves student understanding, with particular effectiveness in subjects requiring spatial visualization and complex concept comprehension. This research contributes to the growing body of knowledge on educational technology integration and provides practical insights for educators seeking to implement AR-based learning solutions.

Keywords: *Augmented Reality, Educational Technology, Student Understanding, Learning Innovation, Interactive Learning.*

How to cite: Laia, P. S., Halawa, Z. K. E. A., Ndruru, I. H., Gulo, S., Zega, S. M., Gulo, J., & Waruwu, Y. (2025). Augmented Reality (AR)-Based Learning Innovation To Improve Student Understanding Subjects. *NUSRA : Jurnal Penelitian Dan Ilmu Pendidikan*, *6*(2), 259–266. https://doi.org/10.55681/nusra.v6i2.3592

INTRODUCTION

The rapid advancement of digital technology has fundamentally transformed educational practices, creating new opportunities for innovative teaching and learning methods (Chen et al., 2017). Augmented Reality (AR), which overlays digital content onto the physical world, has emerged as a particularly promising tool for educational enhancement. This technology enables the creation of interactive learning environments that bridge the gap between theoretical knowledge and practical application (Wu et al., 2013).

In recent years, the educational sector has witnessed a significant shift towards more interactive and technology-enhanced learning approaches. This transformation is driven by the need to engage modern students who are increasingly digital-native and respond better to multimedia-rich learning experiences (Johnson et al., 2016). AR technology offers unique advantages in this context, allowing students to visualize complex concepts, interact with virtual objects in real-time, and engage in experiential learning that would be difficult or impossible to achieve through traditional methods. The integration of AR in education addresses several key challenges in contemporary learning environments. First, it provides a solution to the abstract nature of many academic concepts by offering tangible, visual representations that students can manipulate and explore (Akçayır & Akçayır, 2017). Second, AR technology supports different learning styles and preferences, making educational content more accessible to diverse student populations (Ibáñez & Delgado-Kloos, 2018). Third, it creates opportunities for active, self-directed learning experiences that can enhance student motivation and engagement.

Despite the potential benefits, the effective implementation of AR-based learning solutions requires careful consideration of pedagogical principles, technical requirements, and practical constraints. Previous research has identified various factors that influence the success of AR integration in educational settings, including teacher preparedness, technological infrastructure, and curriculum alignment (Diegmann et al., 2015). Understanding these factors is crucial for developing effective AR-based learning interventions that can meaningfully improve student understanding.

This study aims to investigate the impact of AR-based learning innovations on student understanding across different subject areas. Specifically, it examines: The effectiveness of AR technology in improving student comprehension of complex concepts, The relationship between AR-based learning and student engagement levels, The practical considerations and challenges in implementing AR solutions in educational settings and The potential of AR technology to support personalized learning experiences. Through this research, we seek to contribute to the growing body of knowledge on educational technology integration and provide practical guidelines for educators interested in implementing AR-based learning solutions in their teaching practice.

RESEARCH METHOD

Research Design

This study employed a mixed-methods research design, combining quantitative and qualitative approaches to provide a comprehensive understanding of AR-based learning effectiveness (Creswell & Creswell, 2018). The research was conducted over two academic semesters, following a quasi-experimental design with pre-test and post-test measurements.

Participants

The study involved 180 secondary school students (ages 14-16) and 12 teachers from four different schools. The sample was divided into:

- Experimental group (n=90): Received AR-enhanced instruction
- Control group (n=90): Received traditional instruction

Participants were selected using stratified random sampling to ensure representative distribution across academic performance levels, gender, and previous technology exposure (Johnson et al., 2016).

Instruments and Materials

1. AR Learning Applications
   - Custom-developed AR applications for science and mathematics subjects
   - Commercial AR educational platforms adapted for specific curriculum needs
   - Mobile devices (tablets and smartphones) with AR capabilities
2. Data Collection Tools
   - Pre and post-test assessments aligned with curriculum objectives
   - Student engagement survey (adapted from Wang et al., 2017)
   - Semi-structured interview protocols for teachers and students
   - Classroom observation rubrics
   - Learning analytics data from AR applications

Implementation Procedure

The study was conducted in three phases:

Phases 1: Preparation (4 weeks)

- Teacher training on AR technology implementation
- Pre-testing of students' subject knowledge
- Initial surveys on technology readiness
- Installation and testing of AR applications

Phase 2: Implementation (16 weeks)

- Regular AR-enhanced lessons for experimental group
- Traditional instruction for control group
- Continuous monitoring and data collection
- Bi-weekly classroom observations

Phase 3: Evaluation (4 weeks)

- Post-testing of subject knowledge
- Final engagement surveys
- Interviews with teachers and selected students
- Collection of learning analytics data

Data Analysis

Quantitative data analysis include:

- Descriptive statistics for demographic data
- Independent t-tests comparing experimental and control groups
- ANOVA for multiple group comparisons
- Effect size calculations using Cohen's d
- Regression analysis for identifying predictor variables

Qualitative data analysis involved:

- Thematic analysis of interview transcripts
- Content analysis of observation notes
- Triangulation of multiple data sources

RESULTS

Academic Performance

The analysis of pre-test and post-test scores revealed significant
Improvements in the experimental group:

1. Overall Performance
   - Experimental group: Mean improvement of 27.8% (SD = 4.2)
   - Control group: Mean improvement of 15.3% (SD = 3.9)
   - Significant difference ($t(178) = 8.45$, $p < .001$, $d = 0.89$)
2. Subject-Specific Improvements Physics:
   - Experimental: 31.2% improvement
   - Control: 16.8% improvement
   - ($p < .001$, $d = 0.92$)

Mathematics:

- Experimental: 25.4% improvement
- Control: 14.7% improvement
- ($p < .001$, $d = 0.85$)

Student Engagement

Analysis of engagement metrics showed:

1. Behavioral Engagement
   - 82% increase in class participation
   - 67% reduction in off-task behavior
   - Significantly higher completion rates for assignments ($p < .01$)

2. Emotional Engagement
   - 76% of experimental group reported increased interest
   - 84% indicated preference for AR-based learning
   - Positive correlation between engagement and performance ($r = 0.73$)

Learning Analysis Data

AR application usage patterns revealed:

- Average daily interaction time: 37.5 minutes
- Most frequent usage: Problem-solving activities (42%)
- Peak engagement periods: During interactive simulations
- Completion rate for AR activities: 89%

Qualitative Findings

1. Teacher Perspectives Primary themes identified:
   - Enhanced student visualization capabilities
   - Improved classroom management
   - Need for technical support
   - Time management challenges

2. Student Feedback Key themes emerged:
   - Increased motivation and interest

- Better understanding of abstract concepts
- Technical challenges with devices
- Preference for interactive learning

3. Implementation Challenges Main issues identified:
   - Hardware limitations (21% of cases)
   - Internet connectivity issues (18%)
   - Software compatibility problems (15%)
   - Time constraints (25%)

Correlation Analysis

Significant correlations were found between:

- AR usage time and performance improvement ($r = 0.68$, $p < .001$)
  - Student engagement and learning outcomes ($r = 0.73$, $p < .001$)
  - Technical proficiency and learning gains ($r = 0.56$, $p < .01$)

DISCUSSION

Enhanced Academic Performance Through AR Implementation

The significant improvement in academic performance observed in the experimental group (27.8% vs 15.3% in control group) aligns with previous findings by Ibáñez & Delgado-Kloos (2018), who reported similar positive outcomes in STEM subjects. The particularly strong performance improvements in Physics (31.2%) can be attributed to AR's ability to visualize complex phenomena, supporting Chang & Hwang's (2018) assertion that AR technology is especially effective for teaching abstract scientific concepts.

Several factors contribute to these positive outcomes:

1. Visualization and Spatial Understanding The enhanced performance in subjects requiring spatial comprehension supports Akçayır & Akçayır's (2017) findings that AR technology significantly improves students' ability to understand complex spatial relationships. The ability to manipulate and interact with 3D models in real-time appears to bridge the gap between abstract concepts and practical understanding, as previously suggested by Wu et al. (2016).
2. Interactive Learning Experience The high engagement levels observed (82% increase in class participation) correspond with findings from Chen et al. (2017), who identified interactive learning as a key factor in improving student understanding. The correlation between AR usage time and performance improvement ($r = 0.68$) suggests that active engagement with AR content directly contributes to learning outcomes.

Student Engagement and Motivation

The substantial increase in student engagement metrics aligns with previous research by Cheng & Tsai (2016), who identified enhanced motivation as a key benefit of AR implementation. The observed 76% increase in reported student interest particularly supports Yilmaz's (2016) findings regarding AR's positive impact on learning motivation.

Key aspects of engagement include:

1. Behavioral Engagement The 67% reduction in off-task behavior suggests that AR technology effectively captures and maintains student attention, supporting findings by Fuchsova &

Korecko (2019). The high completion rate for AR activities (89%) indicates sustained engagement throughout the learning process.

2. Emotional Engagement The strong preference for AR-based learning (84%) aligns with Liu et al.'s (2016) research on student attitudes toward educational technology. The positive correlation between engagement and performance (r = 0.73) reinforces the connection between emotional investment and learning outcomes.

Implementation Challenges and Solutions

The identified implementation challenges reflect common obstacles in educational technology integration, as documented by Merchant et al. (2014).

Several key issues warrant discussion:

1. Technical Infrastructure Hardware limitations (21% of cases) and connectivity issues (18%) align with challenges identified by Diegmann et al. (2015). These findings highlight the importance of robust technical infrastructure for successful AR implementation.
2. Pedagogical Integration The time management challenges reported by teachers (25%) echo concerns raised by Wang et al. (2017) regarding the integration of technology into existing curriculum structures. This suggests the need for:
   - Improved teacher training programs
   - Streamlined lesson planning tools
   - Better integration with existing curriculum materials
3. Resource Management The correlation between technical proficiency and learning gains (r = 0.56) emphasizes the importance of adequate training and support, supporting findings by Bacca et al. (2014) on the role of technical competency in educational technology success.

Implications for Educational Practice

The findings have several important implications for educational practice:

1. Curriculum Design The success of AR implementation suggests the need for curriculum redesign to better incorporate interactive technology, as proposed by Johnson et al. (2016). This includes:
   - Integration of AR activities into standard lesson plans
   - Development of AR-specific assessment methods
   - Creation of blended learning approaches
2. Teacher Professional Development The identified challenges highlight the importance of comprehensive teacher training, supporting recommendations by Chang & Hwang (2018) for sustained professional development in educational technology.
3. Resource Allocation The findings suggest the need for strategic resource allocation to support AR implementation, including:
   - Investment in robust technical infrastructure
   - Development of support systems for teachers
   - Creation of standardized AR content libraries

Future Research Directions

Several areas warrant further investigation:

1. Long-term Impact Studies examining the sustained effects of AR-based learning over multiple academic years would provide valuable insights into the technology's long-term effectiveness.
2. Cross-subject Applications Investigation of AR applications across different subject areas could help identify optimal implementation strategies for various disciplines.
3. Personalized Learning Research into the potential of AR technology to support personalized learning pathways could provide insights into maximizing individual student outcomes.

Limitations

Several limitations should be considered:

1. Sample Size and Duration The study's scope was limited to 180 students over two semesters, suggesting the need for larger-scale, longitudinal studies.
2. Technical Constraints Current hardware limitations may have impacted the full potential of AR implementation.
3. Subject Scope The focus on science and mathematics subjects may limit generalizability to other academic areas.

CONCLUSION

This research demonstrates the significant potential of Augmented Reality (AR) technology in enhancing student understanding and engagement across academic subjects. The findings reveal substantial improvements in academic performance, with the AR-implemented group showing a 27.8% increase in overall achievement compared to traditional methods. Key benefits included enhanced visualization of complex concepts, increased student engagement, and improved retention of learning materials.

The study highlights three crucial aspects of successful AR implementation in education: robust technical infrastructure, comprehensive teacher training, and well-designed curriculum integration. While challenges such as hardware limitations and time management constraints exist, the benefits of AR-based learning significantly outweigh these obstacles.

The positive correlations between AR usage and learning outcomes ($r = 0.68$) and between student engagement and performance ($r = 0.73$) strongly suggest that AR technology can serve as an effective tool for modern education. These findings provide valuable insights for educational institutions considering AR implementation and suggest that continued investment in AR-based learning solutions could significantly enhance educational outcomes.

Future educational initiatives should focus on developing standardized AR content, improving technical infrastructure, and providing comprehensive teacher training to maximize the benefits of this innovative teaching approach. As technology continues to evolve, AR-based learning shows promise as a transformative tool in education, capable of creating more engaging, interactive, and effective learning environments.

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