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Effectiveness of Augmented Reality–Based Teaching on Students' Learning Outcomes in Science Classrooms

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Abstract

Augmented Reality (AR) has emerged as a transformative instructional technology capable of enhancing visualization, interaction, and learner engagement in science education. The present study investigates the effectiveness of AR-based teaching on students' learning outcomes in science classrooms. A quasi-experimental pre-test–post-test control group design was adopted with a sample of 60 elementary-level students from a CBSE school. The experimental group received AR-integrated instruction, while the control group was taught using traditional chalk-and-talk methods. Data were collected using a standardized achievement test, a student engagement scale, and an observation checklist. Descriptive statistics and independent-samples *t*-tests were employed for data analysis. The results revealed that students exposed to AR-based teaching achieved significantly higher academic scores and demonstrated greater engagement than those in the control group. The findings indicate that AR enhances conceptual clarity, motivation, interactivity, and retention, supporting its effective integration into science teaching.

Keywords: Augmented Reality, Science Education, Academic Achievement, Student Engagement, Experimental Study

Introduction

Recent advancements in educational technology have significantly influenced teaching–learning processes, particularly in science education, where abstract concepts and complex phenomena often challenge students' understanding. Augmented Reality (AR) overlays digital content onto real-world environments, enabling learners to visualize and interact with scientific concepts in an immersive manner. Such experiential learning environments align with constructivist principles, promoting active engagement and deeper conceptual understanding.

Previous research indicates that AR improves students' motivation, problem-solving skills, and conceptual clarity. However, empirical evidence from Indian school contexts—especially at the elementary level—remains limited. Addressing this gap, the present study examines the impact of AR-based teaching on students' academic achievement and engagement in science classrooms.

Review of Related Literature

Several studies have highlighted the educational potential of AR. Billinghurst (2016) emphasized AR's ability to support interactive learning, while Ibáñez and Delgado (2018) reported improved learning outcomes in STEM education through AR-based instruction. Akçayır and Akçayır (2017) identified AR's role in enhancing visualization, reducing cognitive load, and increasing learner motivation. Despite these benefits, challenges such as technological infrastructure and teacher preparedness have also been reported. Overall, the literature establishes AR as a promising instructional strategy, warranting further empirical validation in diverse educational contexts.

Objectives of the Study

The study was undertaken with the following objectives:

1. To examine the effect of AR-based teaching on students' academic achievement in science.
2. To compare student engagement levels between AR-based teaching and traditional teaching methods.
3. To analyze students' perceptions of the AR-supported learning environment.

Hypotheses

The following null hypotheses were formulated:

- **H_1:** There is no significant difference in academic achievement between students taught using AR-based teaching and those taught using traditional methods.
- **H_2:** There is no significant difference in learning engagement between students in the experimental and control groups.

Methodology

Research Design

A quasi-experimental pre-test–post-test control group design was employed to determine the effectiveness of AR-based teaching.

Sample

The sample consisted of **60 elementary-level students** selected through purposive sampling from a CBSE school of Vijayapura.

Tools Used

- Science Achievement Test (25 items; validated)
- Student Engagement Scale (20 items; Likert-type)
- Observation Checklist for teacher–student interaction
- AR Modules developed using applications such as *UniteAR*, *ARLOOPA*, and *Merge Cube*

Data Analysis and Results

Descriptive Statistics

Table 1 presents the mean, standard deviation, and standard error of mean for both groups.

Table 1: Descriptive Statistics of Achievement Scores

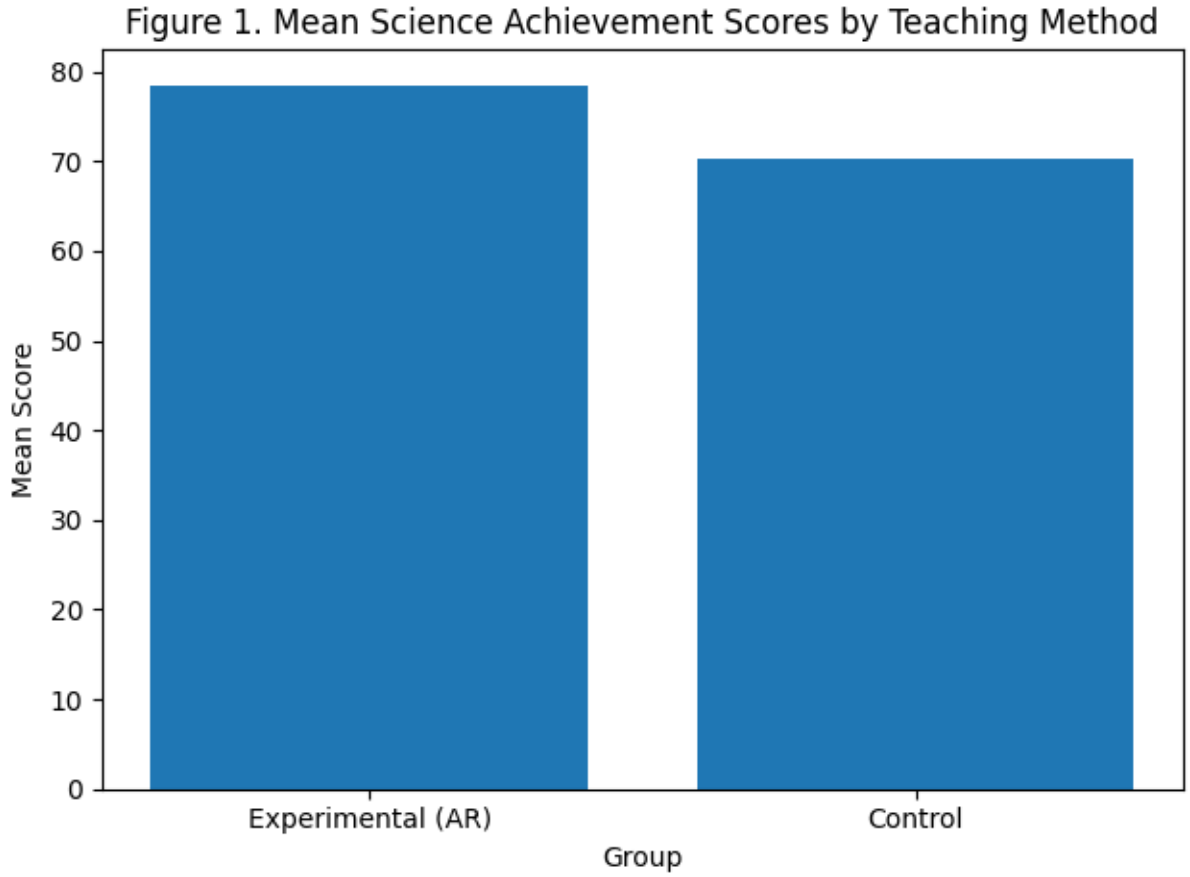
Group	N	Mean	SD	SEM
Experimental (AR)	30	78.50	8.25	1.51
Control	30	70.20	7.90	1.44

Interpretation:

The experimental group achieved a higher mean score (78.50) than the control group (70.20), suggesting a positive effect of AR-based teaching on academic achievement.

Graphical Analysis

Figure 1- Mean science achievement scores of students taught using Augmented Reality (AR)–based instruction and traditional teaching methods.



Interpretation:
The bar graph visually reinforces the descriptive statistics, clearly indicating superior performance by students exposed to AR-based instruction.

Inferential Statistics
To test the significance of the observed difference, an independent-samples *t*-test was conducted.

Table-2: Independent-Samples t-Test for Achievement Scores

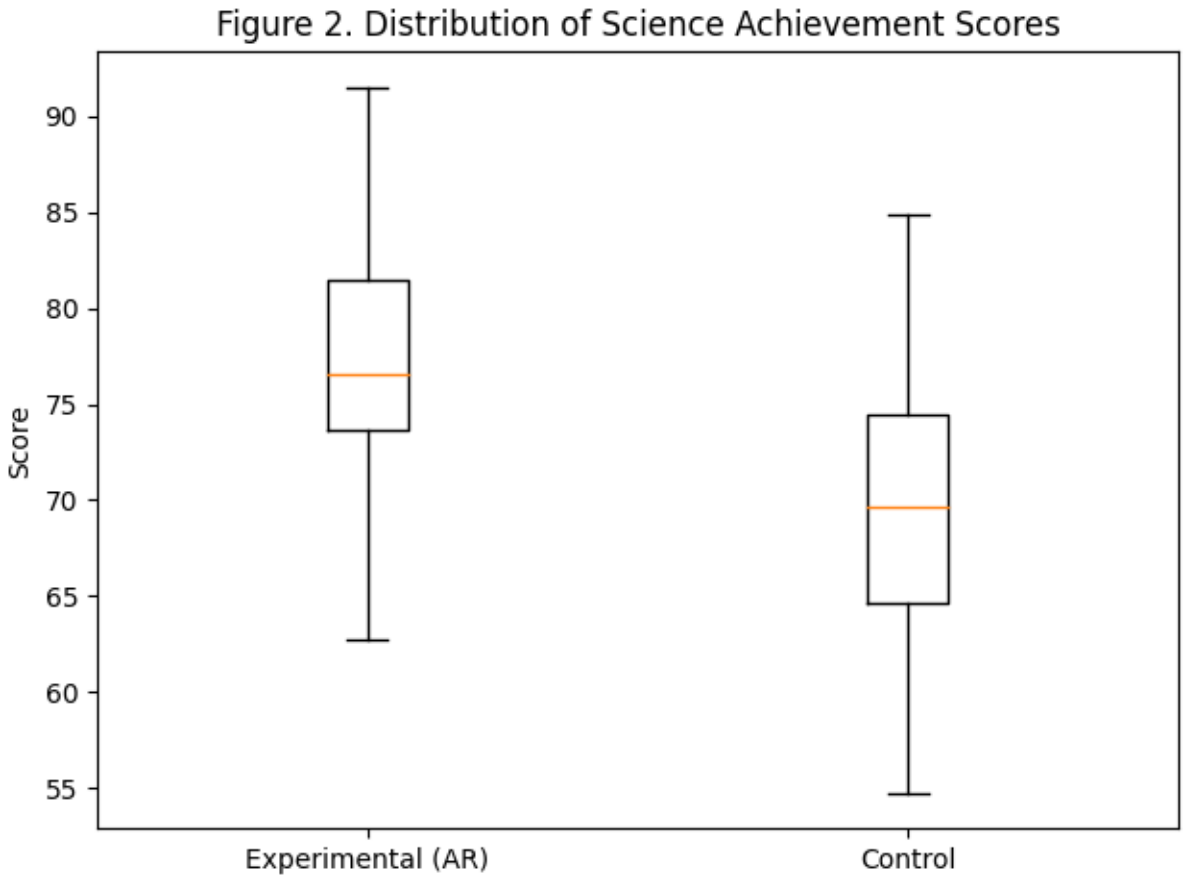
Comparison	*t*	df	*p*	Result
AR vs. Traditional	3.98	58	.0002	Significant

Interpretation:
The obtained *t*-value (3.98) is statistically significant at the 0.01 level ($p < .01$). Hence, **H_1 is rejected**, indicating a significant difference in academic achievement in favor of AR-based teaching.

Distribution of Scores

Figure 2

Distribution of science achievement scores of experimental (AR-based teaching) and control (traditional teaching) groups.



Interpretation:

The distribution graph demonstrates that achievement scores of the AR group are consistently higher and more clustered than those of the control group, suggesting improved performance and learning consistency.

Major Findings

- AR-based teaching significantly improved students' science achievement.
- Students exposed to AR demonstrated higher engagement and motivation.
- AR made abstract scientific concepts more concrete and visually accessible.
- Learners expressed positive perceptions toward AR tools and supported their regular classroom use.
- AR promoted experiential learning and improved retention.

Educational Implications

- AR can be effectively integrated into science curricula, particularly for conceptually complex topics.

- Teacher training programs should include AR tool development and pedagogical integration.
- Schools should invest in digital infrastructure to support AR-based instruction.
- AR-based assessments may be developed to evaluate conceptual understanding.

Suggestions for Future Research

- Longitudinal studies to examine retention effects of AR-based learning.
- Comparative studies involving AR, VR, and AI-assisted instruction.
- Replication studies with larger and more diverse samples.
- Exploration of AR applications in inclusive and special education settings.

Conclusion

The study conclusively demonstrates that Augmented Reality–based teaching is more effective than traditional instructional methods in enhancing science learning outcomes. AR improves visualization, engagement, and academic achievement, making it a valuable pedagogical tool for contemporary science education. The findings strongly support the integration of AR into mainstream educational practices to foster interactive, learner-centered, and future-ready classrooms.

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