QUASI-EXPERIMENTAL STUDY ON THE IMPACT OF ARTIFICIAL INTELLIGENCE IN TRANSFORMING SCIENCE EDUCATION

NISHTHA K. SOLANKI
Research Scholar, Department of Education, Sardar Patel University
Assistant Professor, Sardar Patel College of Education, Bakrol

Abstract:

The integration of Artificial Intelligence (AI) into education has revolutionized traditional pedagogical frameworks, particularly in the domain of science education. This quasi-experimental study aims to assess the transformative potential of AI-based instruction in enhancing students' academic performance, conceptual understanding, and engagement levels. The research involved a comparison between a control group receiving conventional science instruction and an experimental group exposed to AI-integrated learning environments. Quantitative data were collected through standardized pre- and post-tests, while qualitative data were gathered via teacher observations and student feedback instruments.

Findings from this study reveal a statistically significant improvement in the post-test scores of students in the AI-supported classrooms, suggesting that AI contributes positively to the learning process by personalizing content delivery, providing instant feedback, and fostering interactive problem-solving environments (Holmes et al., 2019; Luckin et al., 2016). Moreover, the study recorded higher levels of motivation, curiosity, and student autonomy in the experimental group, further confirming AI's role in transforming passive learning into an active and inquiry-based process (Zawacki-Richter et al., 2019).

This research underscores the importance of embedding AI into science curricula to meet the evolving needs of 21st-century learners. However, it also acknowledges barriers such as technological access, teacher training, and ethical concerns surrounding data use. The study concludes with practical recommendations for educators and policymakers aimed at fostering inclusive, AI-enabled educational ecosystems that support continuous innovation and improved learning outcomes in science education.

Keywords: Artificial Intelligence, Science Education, Quasi-Experimental Study, Student Engagement

Introduction:

The rapid advancement of technology has profoundly influenced educational practices worldwide, with Artificial Intelligence (AI) emerging as a transformative force in teaching and learning. AI refers to computer systems capable of performing tasks that typically require human intelligence, such as problem-solving, pattern recognition, and adaptive learning (Luckin et al., 2016). In the context of education, AI offers innovative opportunities to personalize instruction, automate routine tasks, and provide immediate feedback, thereby addressing some of the long-standing challenges in traditional classrooms.

Science education, in particular, stands to benefit significantly from AI integration due to its complex concepts and the need for hands-on, inquiry-based learning approaches. Conventional teaching methods often rely heavily on lecture-based delivery, which may not adequately engage all learners or accommodate diverse learning styles (Holmes et al., 2019). AI-powered tools such as intelligent tutoring systems, virtual labs, and adaptive assessments can offer tailored learning experiences that promote deeper conceptual understanding and critical thinking skills essential for scientific literacy.

Despite the growing interest in AI applications in education, empirical research specifically investigating its impact on science teaching and learning remains limited. Most existing studies focus on higher education or general educational contexts without delving into subject-specific outcomes or using rigorous experimental designs. To bridge this gap, this study employs a quasi-experimental design to compare the effectiveness of AI-supported science instruction against traditional teaching methods among Grade 9 students.

The study aims to evaluate not only academic achievement but also student engagement and motivation, recognizing that affective factors play a crucial role in learning outcomes. By exploring how AI tools influence these dimensions, the research seeks to provide evidence-based insights for educators and policymakers aiming to enhance science education through technology-driven pedagogies.

Literature Review:

The integration of Artificial Intelligence (AI) into educational contexts has been widely studied in recent years, with numerous researchers highlighting its transformative potential. AI in education encompasses a variety of tools and techniques, including intelligent tutoring systems, adaptive learning platforms, machine learning algorithms, and natural language processing all of which aim to enhance learning outcomes through personalization, interactivity, and automation (Luckin et al., 2016).

Holmes et al. (2019) argue that AI holds the capacity to individualize instruction by adapting content in real time to suit learners' pace, prior knowledge, and performance. This adaptive approach enables students to receive tailored feedback and learning pathways, which can lead to improved retention and conceptual understanding. Moreover, AI technologies can support teachers by automating administrative tasks, identifying learning gaps, and providing data-driven insights into student progress (Baker & Inventado, 2014).

In the domain of science education, the need for innovative pedagogical strategies is particularly pressing due to the abstract and conceptual nature of many scientific topics. Simulations, virtual laboratories, and AI-powered visualizations have been shown to foster inquiry-based learning and stimulate scientific curiosity (Zawacki-Richter et al., 2019). Woolf (2010) emphasizes that AI tools can create engaging environments where students experiment, hypothesize, and visualize scientific phenomena, thus promoting deeper cognitive engagement.

Despite these advances, there is a scarcity of empirical research specifically evaluating the effectiveness of AI in science education within school settings. Most existing studies focus on higher education or general subjects, leaving a research gap concerning how AI impacts student achievement and engagement in secondary science classrooms (Zawacki-Richter et al., 2019; Holmes et al., 2019). Furthermore, challenges such as unequal access to technology, lack of teacher training, and ethical concerns around student data privacy continue to limit the widespread implementation of AI tools in classrooms (Luckin et al., 2016).

This study aims to contribute to the existing body of knowledge by conducting a quasi-experimental analysis comparing traditional science teaching methods with AI-enhanced instruction, thereby providing evidence-based insights into the practical benefits and challenges of integrating AI in school-level science education.

Methodology:

Research Design:

This study employed a quasi-experimental research design involving non-randomized control and experimental groups to evaluate the impact of AI in science education. The quasi-experimental design is particularly suitable in educational settings where random assignment may be impractical due to ethical or logistical constraints (Creswell & Creswell, 2018). The control group received instruction through traditional teaching methods, while the experimental group was exposed to AI-integrated tools and platforms tailored to science curriculum objectives.

Sample:

The sample comprised 60 Grade 9 students from two comparable secondary schools. Each group included 30 students with similar demographic and academic backgrounds to maintain equivalence in baseline characteristics. This approach ensured that any observed differences in learning outcomes could be attributed more confidently to the instructional method rather than external variables.

Three primary instruments were used for data collection:

- Pre- and Post-Test Assessments were designed based on curricular standards to evaluate changes in students' conceptual understanding of science topics.
- A Student Engagement Questionnaire, adapted from validated models (Fredricks et al., 2004), measured students' motivation, attention, and satisfaction.
- Teacher Observation Checklists recorded classroom dynamics, student participation, and the functional integration of AI tools during instruction (Luckin et al., 2016).

This multi-method approach provided both quantitative and qualitative insights into the effectiveness of AI in science teaching.

Statistical Analysis:

This study employed both descriptive and inferential statistical methods to evaluate the impact of Artificial Intelligence (AI) integration on science learning outcomes among Grade 9 students.

Descriptive Statistics:

The pre-test and post-test scores were analysed to understand the improvement in conceptual understanding within each group. The control group, taught through traditional instruction, improved from a mean pre-test score of 62.4 to a post-test mean of 68.2, reflecting a 9.3% improvement. In contrast, the experimental group, which received AI-integrated instruction, showed a substantial increase from 61.9 to 78.7, marking a 27.2% improvement.

Table 1: Descriptive Summary of Test Scores

Group	Pre-Test Mean	Post-Test Mean	Improvement%
Control group	62.4	68.2	9.3%
Experimental group	61.9	78.7	27.2%

Inferential Statistics:

To validate the statistical significance of these improvements, paired sample t-tests were conducted within each group. The results indicated that both groups showed statistically significant gains from pre- to post-test ($p < 0.05$). However, the experimental group exhibited a far greater improvement.

Additionally, an independent sample t-test was applied to compare the learning gains between the two groups. The difference in mean improvement was found to be statistically significant ($p < 0.05$), favouring the AI-supported instructional approach. This implies that AI tools had a more positive impact on learning outcomes compared to traditional methods.

Table 2: Inferential Test Results:

Test	Comparison	t-Value	p-Value	Result
Paired Sample t-test	Control: Pre vs. Post	2.48	0.018	Significant
Paired Sample t-test	Experimental: Pre vs. Post	5.32	0.000	Significant
independent Sample t-test	Control vs. Experimental Gains	3.97	0.0004	Significant

(Note: $\alpha = 0.05$; significance determined at the 5% level.)

The findings corroborate earlier studies that emphasize AI's role in enhancing academic performance by personalizing learning pathways and enabling real-time feedback (Luckin et al., 2016; Holmes et al., 2019).

Result and Discussion:

The results of this quasi-experimental study clearly indicate that students in the AI-integrated instructional group significantly outperformed those in the control group on both academic achievement and engagement metrics. The experimental group, which utilized AI tools such as intelligent tutoring systems, real-time feedback platforms, and interactive simulations, demonstrated a mean post-test score of 78.7 compared to 68.2 in the control group, confirming a statistically significant improvement ($p < 0.05$).

This finding aligns with previous research suggesting that AI-enhanced learning environments can optimize student outcomes by offering personalized feedback, adaptive content delivery, and increased learner autonomy (Holmes et al., 2019; Luckin et al., 2016). Students in the AI-supported group benefitted from differentiated instruction tailored to their individual needs and learning pace, allowing for more effective conceptual understanding of complex scientific principles.

Observational data gathered from classroom interactions further reinforced these results. Teachers noted a marked increase in student curiosity, collaborative engagement, and problem-solving efforts in the AI group. Students interacted more frequently with the content and with one another, utilizing AI features such as instant quizzes, interactive models, and scaffolding prompts, which enhanced motivation and participation (Woolf, 2010).

Moreover, the Student Engagement Questionnaire results indicated higher levels of satisfaction, enjoyment, and perceived relevance of science content among the experimental group. These results support the hypothesis that the integration of AI into science instruction can transform passive learning into active, inquiry-based learning, thus improving both cognitive and affective outcomes (Zawacki-Richter et al., 2019).

In summary, the findings demonstrate that AI not only elevates academic performance but also fosters a richer, more engaging learning environment. This supports the ongoing shift toward technology-enhanced pedagogies in science education and highlights the potential of AI to address traditional classroom limitations through data-driven personalization and enhanced student agency.

Conclusion:

This study provides compelling evidence that the integration of Artificial Intelligence (AI) in science education results in significant improvements in both student performance and engagement. The quasi-experimental findings indicate that AI-supported instruction not only enhances conceptual understanding but also fosters greater motivation and active participation among learners. These outcomes align with previous research emphasizing AI's capability to personalize learning experiences, adapt to individual student needs, and provide immediate feedback, thereby facilitating deeper comprehension and retention of scientific concepts (Luckin et al., 2016; Holmes et al., 2019).

The results suggest that AI-driven tools can serve as a viable and effective alternative to traditional teaching methods, particularly in addressing the diverse learning paces and styles that characterize contemporary classrooms. The increased interaction and engagement observed in AI-integrated settings highlight AI's potential to transform science education into a more dynamic, student-centered process (Zawacki-Richter et al., 2019).

However, despite these promising benefits, several challenges must be acknowledged. Teacher readiness remains a critical factor, as effective AI implementation requires educators to be adequately trained not only in the technical aspects but also in pedagogical strategies for AI integration (Baker & Inventado, 2014). Infrastructure constraints, including limited access to reliable internet and hardware, pose additional barriers, especially in under-resourced schools (Luckin et al., 2016). Furthermore, issues of equitable access and data privacy must be addressed to ensure that AI-enhanced learning environments are inclusive and ethically managed.

Future research should explore the long-term effects of AI in science education, including its impact on higher-order thinking skills and knowledge transfer. Broader implementation strategies that consider diverse educational contexts and scalability are also necessary. Addressing these areas will be crucial for maximizing the transformative potential of AI and creating sustainable, effective science education models for the future.

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