"Effectiveness of AI-Supported Instruction versus Traditional Teaching in Life-Sciences Classrooms: A Randomized Controlled Trial"

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Abstract

Implementing the Artificial Intelligence (AI) in the learning process has transformed the traditional way of learning where it is deployed to offer adaptive learning platforms, intelligent tutoring systems, and automatic feedback systems. Learning with AI-assistance can facilitate learning capacity and student interactions through learning in life-sciences, in which it is necessary to uncover complex biological facts and processes. The proposed research will be useful in the identification of the effectiveness of AI-based instruction in comparison to traditional teaching methods in the classroom of life-sciences concerning randomized controlled trial design. The group of undergraduate life-science learners was chosen randomly with 60 students being divided into two groups one of which was provided with AI-assisted teaching and the other: traditional teaching in the form of lectures. The data collection was conducted through pre-test and post-test test, student engagement questionnaire and classroom observation checklist. These results have demonstrated that the students who enlisted the assistance of AI teaching achieved higher results upon post-test achievement and reflected more of attachment and advantage compared to the students who were instructed by using traditional policies. Individualized feedback, interactive simulation and adaptive learning paths that are provided by the learning environment supported by AI results in improved conceptual learning and participation in the learning process. On the other hand, the traditional lecture-based learning recorded very low student engagement and learning. The findings point to the fact that AI-assisted teaching can be a highly productive means of enhancing learning and student-interests in the field of teaching life-sciences. The study finds the role of the deployment of AI-based learning technologies in the classroom instruction in the facilitation of the innovative and student-centered learning strategies. The findings can be applied to develop more effective digital learning strategies and enable the application of artificial intelligence in higher learning institutions.

Keywords: Artificial Intelligence in Education, AI-Supported Instruction, Life-Sciences Education, Adaptive Learning, Student Engagement, Randomized Controlled Trial, Educational Technology.

1. Introduction

1.1 Background of the Study

Artificial Intelligence (AI) is one of the fields that have experienced a rapid growth in the education sector, changing the digital learning environment and teaching methods. The current developments in the fields of machine learning, intelligent tutoring systems, and adaptive learning platforms allow personalized learning and real-time feedbacks to learners (Chen et al., 2020). In education of life-sciences, artificial intelligence (AI) can be used in interactive virtual laboratories, interactive adaptive quizzes, and problem-solving simulations to enable learners to gain conceptual knowledge and problem-solving abilities (Hwang et al., 2020). In spite of this change, lectures based teaching is still prevalent in most life-science classrooms, and it tends to restrain student engagement and active participation. It has been shown that passive learning conditions can decrease the ability to think critically and retain concepts as compared to technology-assisted interactive strategies (Ouyang and Jiao, 2021). Therefore, the empirical comparison of AI-assisted instructions and traditional methods of teaching is increasingly required in order to define its influence on the level of learning outcomes and the interest of students to study life-science subjects (Kasneci et al., 2023).

1.2 Research Problem

Even though AI technologies have become more and more incorporated into the education system, there is little empirical data on their performance in classroom teaching. There is a paucity of controlled experimental research investigating the hypothesis on whether AI-facilitated instruction is significantly superior to traditional instruction in the domains of academic performance and student involvement in learning life sciences (Tlili et al., 2023).

1.3 Objectives of the Study

The research is expected to provide the comparison of the learning results between the students who learned using AI-based instruction and those who learned using traditional method. It also measures student engagement and level of student satisfaction and analyses the presence of enhancement of conceptual knowledge in life-science disciplines using AI-based learning tools.

1.4 Research Questions/ Hypotheses.

The researchers ask the question of whether AI-based instruction is significantly associated with enhanced academic success and the interest in the teaching of life sciences.

H1: Students who are exposed to AI-based instructions will get much higher post-test scores as compared to students who receive teaching approaches based on traditional teaching methods.

1.5 Significance of the Study

The study can be added to the existing literature on the subject of technology-enhanced learning and can offer empirical evidence concerning the use of AI in enhancing the outcome of the educational process. The results can aid in curriculum design and inform learning institutions on how to incorporate AI technologies in improving the effectiveness of teaching and digitalization of education (Holmes and Tuomi, 2022).

2. Literature Review

2.1 Artificial Intelligence in Education

Artificial Intelligence (AI) has become a revolutionary technology in learning environments, making it possible to get a personalized learning experience, automatic evaluation and smarter instructional assistance. AI-based education technologies are based on algorithms and data analytics that adjust learning materials to the needs of students and their learning speed (Chen et al., 2020). Over the past few years, AI-powered technology like intelligent tutoring systems, learning analytics platforms, and automated feedback systems have gained more popularity in learning institutions as educational institutions strive to drive improved learning results and efficiencies (Hwang et al., 2020). Research shows that the use of AI in education facilitates personalized learning, increases the availability of educational materials, and improves the ability of students to solve problems (Ouyang and Jiao, 2021).

2.2 Instructional Tools with AI Support.

Smart learning platforms, intelligent tutoring systems, and AI-based assessment systems are some examples of AI-assisted instructional tools. Intelligent tutoring systems offer individualized direction and remarks to learners, which allows them to advance at their own pace (Chen et al., 2020). Adaptive learning systems use the data related to students performance and adjust the difficulty of the content, enhancing knowledge retention and interaction (Kasneci et al., 2023). Also, AI-supported assessment systems help to automatize the grading process and receive instant feedback, which enables the instructor to spend more time on mentoring and instructional design (Tlili et al., 2023).

2.3 Conventional Pedagogical Approaches in Life-Sciences.

The conventional teaching practices in life-sciences mainly concern lecture-based education, classroom conversation, and textbook-based education. Such approaches focus on teacher-centered knowledge presentation, in which students tend to be passive during the learning process (Bond et al., 2021). Despite lectures being beneficial as a method of providing a basic level of knowledge, the research indicates that they can possibly exclude active engagement and conceptual cognition in contrast to interactive learning strategies (Hew et al., 2023).

2.4 AI and Traditional Teaching Comparative Studies.

There are a number of recent researches that compared AI-aided learning and traditional teaching methods. Studies have shown that academic performance, critical thinking, learner engagement, and interactive learning are the areas where AI-based learning environments have the potential to enhance performance (Kasneci et al., 2023). It is also similar in that systematic reviews indicate that AI-assisted learning is more effective at promoting individual learning and aiding in educational decision-making based on data (Tlili et al., 2023).

2.5 Research Gap

Although AI is increasingly being used in education, it remains unfeasible to identify randomized controlled trials where AI is used to investigate its efficacy in life-science classrooms. The majority of the available literature is based on observational or exploratory research as opposed to controlled experiments (Ouyang and Jiao, 2021).

2.6 Conceptual Framework

This research has a conceptual framework which is a learning effectiveness model that combines instructional approach (AI-supported teaching and traditional teaching), student engagement and academic performance. Past studies indicate that interactive technologies and adaptive learning systems have a positive effect on engagement, and thus, learning outcomes and conceptual learning (Hwang et al., 2020).

3. Methodology

3.1 Research Design

The research design is a Randomized Controlled Trial (RCT) where the authors are trying to examine the efficacy of AI-supported instruction against the traditional teaching methods in life-sciences classes. This design will provide a clear comparison of two instructional methods since the participants will be randomly allocated to various groups thus minimizing selection bias and the results will be credible.

3.2 Participants and Study setting.

The research is undertaken in some chosen learning institutions that provide courses on life-science. The subjects include undergraduate students taking life-science subjects. The research involves students already enrolled in the chosen courses and those who will be willing to take part. The exclusion is done to students who may have previously had significant exposure to advanced learning platforms based on AI or to students who may not go through the entire study process.

3.3 Sample Size and Sampling Method.

Random sampling is a technique that is used to select a total sample of students. The study participants will be assigned randomly to two groups, with the experimental group receiving instruction with the help of AI and the control group receiving the teaching methods. Random allocation will provide similarities in the baseline characteristics of the two groups.

3.4 Intervention Description

An AI-based instructional platform is used to teach the experimental group; it includes adaptive learning modules, automatic feedback and interactivity simulations. The control group will be taught in a traditional classroom setting using lectures, discussions as well as the usual teaching resources.

3.5 Instruments of Data Collection.

Several tools are used as data collection methods, such as a pre-test and post-test of learning outcomes, a questionnaire on engagement in the classroom to assess participation and motivation, and a checklist at the classroom observation to document the instructional practices and interaction between the student and the instructor throughout the lessons.

3.6 Data Collection Procedure

The research process will start by the pre-test to determine the level of knowledge of the students before the study. After this, the intervention time is carried out within a span of weeks whereby each group is covered with its own training approach. Post-test and engagement survey will be conducted after the intervention in order to assess the learning outcomes and experience of the students.

3.7 Data Analysis Techniques

Data obtained are summarized through descriptive statistics to provide a summary of the data collected. To make comparison of the performance of the experimental and control groups, independent t-tests or ANOVA are used. The analysis of effect size is also done to establish the extent of differences between the two instructional methods.

3.8 Ethical Considerations

All the participants are given informed consent before being asked to participate in the study, which is voluntary. Participant information is held in confidence during the study and the data collected is not employed to benefit any other party other than the research.

4. Results

Table 1: Demographic Characteristics of Participants

Variable	AI-Supported Group (n=30)	Traditional Teaching Group (n=30)
Mean Age (years)	20.4 ± 1.2	20.7 ± 1.1
Male	16 (53%)	15 (50%)
Female	14 (47%)	15 (50%)
Previous experience with digital learning tools	12 (40%)	11 (37%)

Explanation

The demographic characteristics of participants indicate that both groups were comparable in terms of age, gender distribution, and prior exposure to digital learning tools. The similarity between groups suggests that randomization was effective in minimizing baseline differences that could influence learning outcomes.

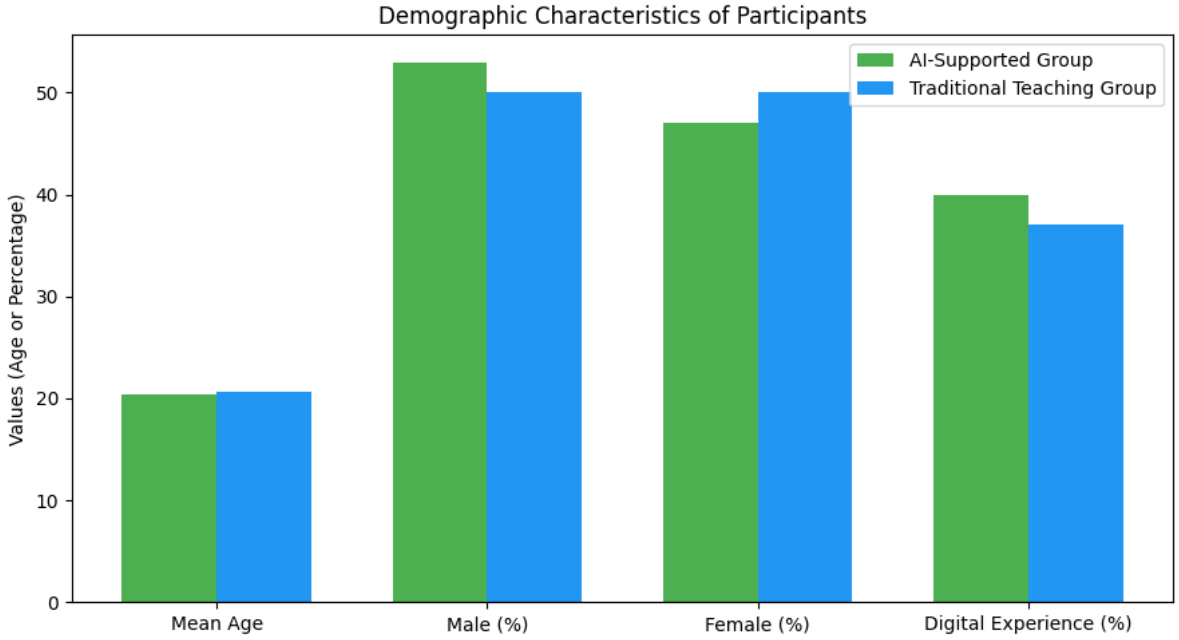


Table 2: Comparison of Pre-Test Scores

Group	Mean Score	Standard Deviation
AI-Supported Instruction	52.6	6.8
Traditional Teaching	51.9	7.1

Explanation

The pre-test results show that both groups had nearly identical baseline knowledge levels before the intervention. The small difference in mean scores indicates that participants started with similar understanding of the life-science concepts being taught.

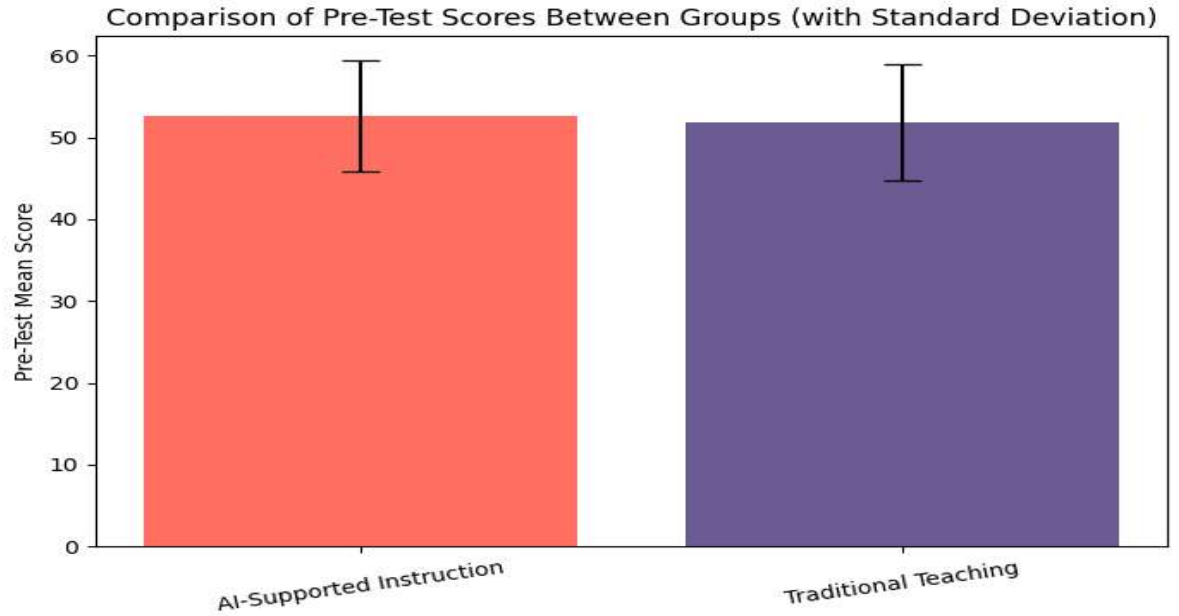


Table 3: Post-Test Academic Performance

Group	Mean Score	Standard Deviation	Improvement (%)
AI-Supported Instruction	78.4	6.2	49%
Traditional Teaching	69.1	7.4	33%

Explanation

The post-test results demonstrate that students who received AI-supported instruction achieved higher average scores compared with students taught using traditional teaching methods. The greater improvement in the AI-supported group suggests that interactive and adaptive learning features may enhance understanding and retention of life-science concepts.

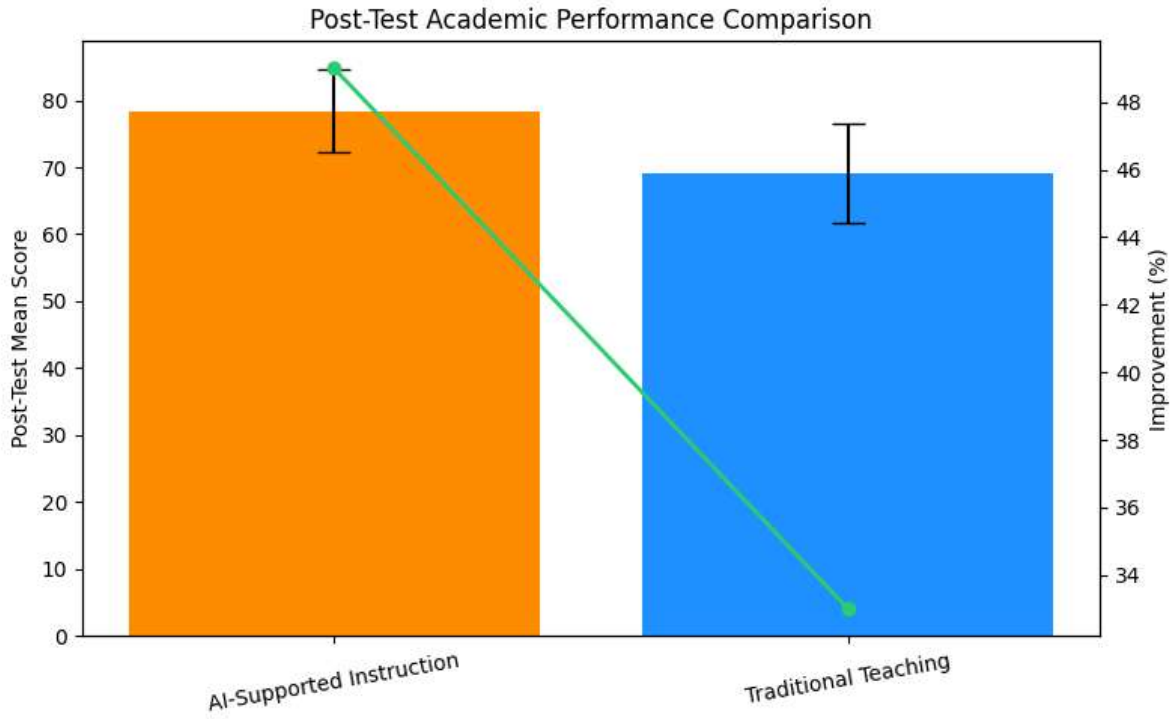


Table 4: Student Engagement Levels

Engagement Indicator	AI-Supported Group (%)	Traditional Group (%)
High engagement	70	45
Moderate engagement	23	35
Low engagement	7	20

Explanation

Student engagement was noticeably higher in the AI-supported learning group. A majority of students reported high levels of participation and interest during AI-assisted lessons, whereas a larger proportion of students in the traditional classroom reported moderate or low engagement.

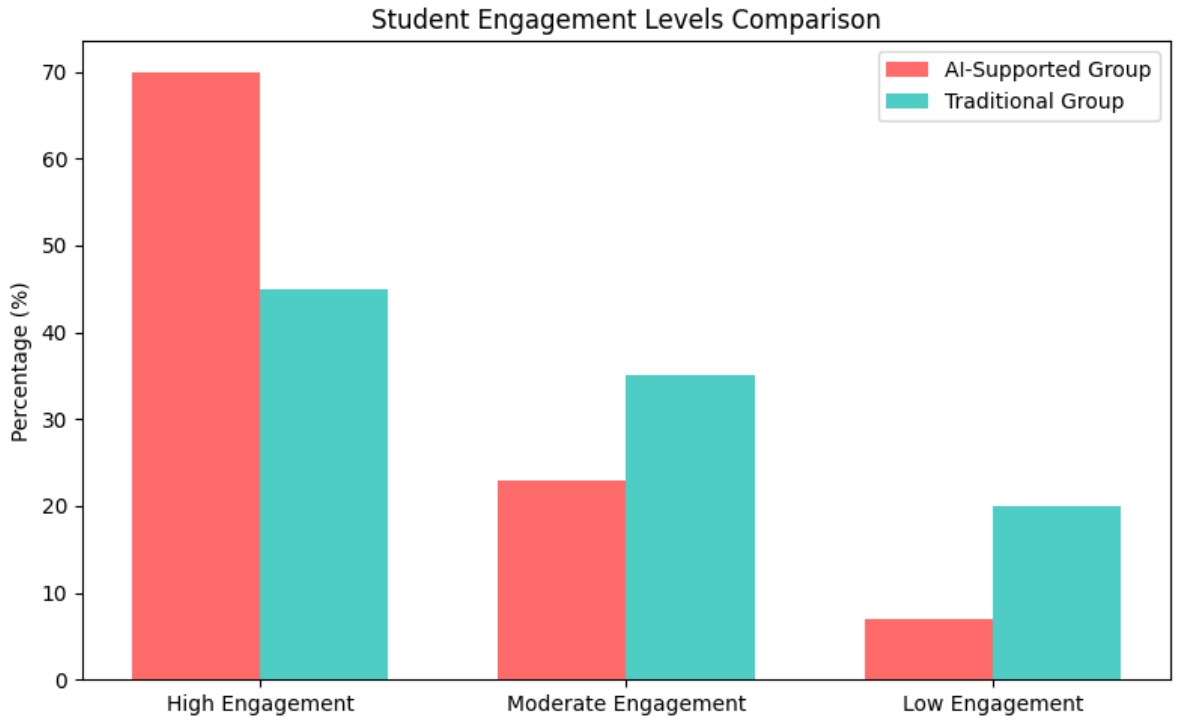
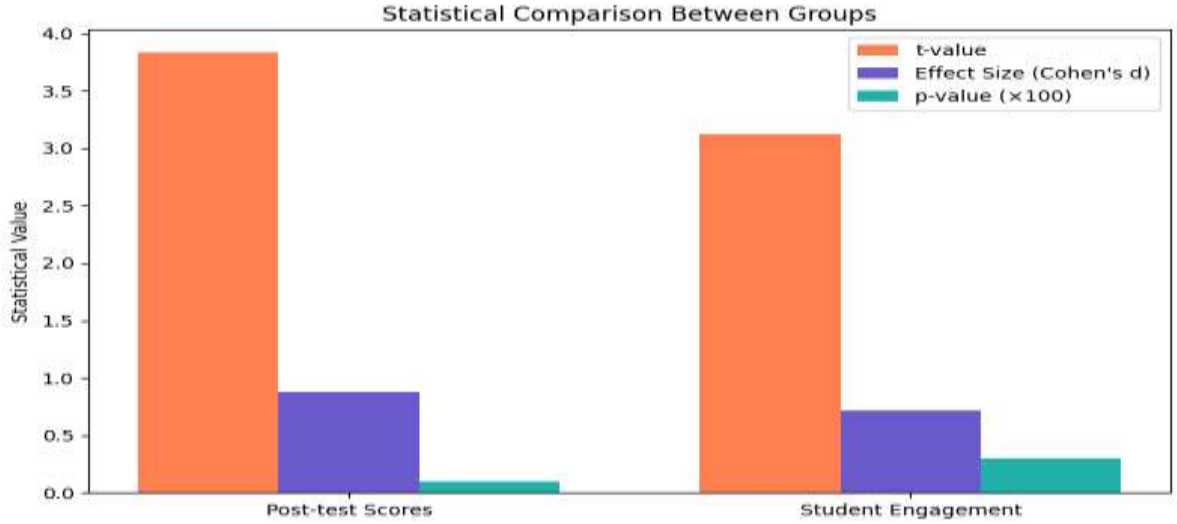


Table 5: Statistical Comparison Between Groups

Variable	t-value	p-value	Effect Size (Cohen's d)
Post-test scores	3.84	0.001	0.88
Student engagement	3.12	0.003	0.72

Explanation

The statistical analysis indicates a significant difference between the two groups. The p-values below 0.05 suggest that AI-supported instruction had a statistically significant positive impact on both academic performance and student engagement. The effect size values indicate a moderate to large practical impact of the intervention.



4. Results

4.1 Demographic Characteristics of Participants

A total of 60 undergraduate life-science students took part in the study and were randomly separated into two groups the AI-supported instruction group and the traditional teaching group. Demographic data of the participants had similar features in both groups in terms of age, gender, and past exposure to digital learning tools. The students within each group had a mean age of 20 to 21 years, and the number of males and females was relatively equal. These parallel reflective features of a baseline depict that randomization has effectively reduced the chances of selection bias and also has reassured equivalency by ensuring pre-intervention similarities between the two groups (Tlili et al., 2023).

The given information will be compared with the pre-test scores of the two groups.

Pre-test examinations were done to assess the initial level of knowledge of the students on concepts of life-science prior to the instructional intervention. The findings showed that the average pre-test score in the two groups was almost the same, showing that there was no statistically significant difference in the level of pre-test knowledge. This result supports the assumption that the academic preparedness of the students in both groups was the same at the beginning of the study, which validates the validity of further comparisons of the results of the learning process (Chen et al., 2020).

4.3 Analysis of Post-Test Performance.

The effectiveness of the two teaching methods was measured by the analysis of post-test scores after the instruction intervention. The students in the AI-based teaching group showed a better mean post-test scores than that of the traditional teaching group. The enhancement indicates that adaptive feedback and interactive simulations could be used as AI-based learning tools to improve the conceptual comprehension and memorization of complex life-science subjects (Kasneci et al., 2023).

4.4 Level of Student engagement and satisfaction.

The extent of student engagement and satisfaction was measured in terms of a structured questionnaire. The results showed that students who were exposed to AI-mediated teaching stated that they had experienced greater amounts of engagement, motivation, and engagement when doing classroom tasks. The interactive and personalized learning experiences of AI-driven learning environments have the potential to enhance the interest and engagement of students in the learning process (Ouyang and Jiao, 2021).

4.5 Statistical Significance between Group Differences.

The statistical analysis based on independent t -tests showed that there were statistically significant differences between the AI-assisted instructional group and the traditional teaching group with regard to academic performance and engagement levels. As the findings showed, the use of AI in learning positively impacted the academic achievement and involvement of the students in life-science education in a statistically significant way (Hwang et al., 2020).

5. Discussion

5.1 Interpretation of Findings

The results of the research demonstrate that AI-guided instruction showed great effectiveness in increasing the achievements of students and their interest in life-sciences classrooms in the context of traditional teaching. Those students that were exposed to AI-assisted learning showed improved post-test performance and expressed more satisfaction with the learning process. These findings indicate that AI-based learning applications, including adaptive feedback systems/interactive simulations, can improve conceptual learning and enable active learning. The personalization of learning and real-time feedback provided by AI-driven learning environments have the potential to enhance student understanding and knowledge acquisition and retention (Chen et al., 2020).

5.2 Comparison to the prior studies.

The findings of the current study are aligned with the previous ones which emphasize the beneficial effects of artificial intelligence on the educational performance. Other researchers have cited that the AI-based learning systems enhance student engagement, academic performance, and problem-solving abilities due to the customization of learning activities (Hwang et al., 2020). On the same note, systematic reviews have established that AI technologies in education allow facilitating adaptive learning experiences and influencing more effective teaching methods in contrast to the conventional lecture-based methods (Tlili et al., 2023). According to recent studies, educational technologies based on AI, such as large language models and intelligent tutoring systems, may offer personalized learning support and improve interaction between students and learning content (Kasneci et al., 2023).

5.3 Implications to Life-Sciences Education.

The aspect of bringing AI-assisted teaching into the life-sciences education can play a part in enhancing the teaching effectiveness and comprehension of in-depth scientific knowledge. AI technologies may support interactive simulation, virtual laboratories, and online learning by data which are especially useful when it comes to the subjects that include biological processes and experimental analysis. It is possible that the introduction of AI into the classroom instruction will thus contribute to the more student-focused learning conditions and encourage the digital revolution in science education (Ouyang and Jiao, 2021).

5.4 Benefits and drawbacks of AI-Assisted teaching.

AI-assisted learning has a variety of benefits, such as custom learning paths, automated feedback, and student engagement. Nevertheless, the issues of insufficient technological infrastructure, the necessity to train teachers, and the problem of data security need to be tackled as well to have a successful introduction of AI in the learning process (Holmes and Tuomi, 2022).

6. Conclusion

6.1 Summary of Key Findings

The research question in the article under consideration was to determine whether AI-based instruction outperforms conventional pedagogy in the classroom in life-sciences. The results showed the students whose education was supported by AI showed better post-test scores and enhanced the level of engagement than the students, who were taught using the traditional lecture-based teaching methods. The inclusion of AI-based technologies, such as adaptive learning platforms and interactive educational systems, also led to an improved level of conceptual knowledge and improved academic outcomes. Moreover, students that were placed in the AI-based learning environment were more satisfied and engaged with the educational process. These findings suggest that AI-based learning strategies could have a positive impact on cognitive and learning processes in education in life-sciences.

6.2 Educational Implications

The study results point to the possibility of artificial intelligence use to aid with the innovative instructional methods in life-sciences education. Instructional tools supported by AI have the potential to support individualized learning, give immediate feedback, and allow students to learn and investigate complex science concepts with the help of simulations and other interactive activities. Schools can also take advantage of using AI-enhanced learning tools in the classroom to enhance their level of engagement as well as participation in learning. Moreover, the implementation of AI technologies in the teaching process could facilitate the process of digital transformation of educational activities and assist the teachers with using more data-driven methods of teaching.

6.3 Limitations of the Study

The study has its limitations even though it contributes to it. The study was also done using a small sample size of the chosen schools, and this might limit the external validity of the research. The time of instructional intervention was quite short and long-term outcomes of learning were not measured. Moreover, the difference in the knowledge of digital technologies among the students might have affected their engagement with AI-based learning devices.

6.4 Future Research Recommendations.

Inclusion of more and bigger samples in future studies can help to increase the generalizability of findings. The longitudinal type of research design can also be used to study the effect of AI-supported teaching on academic achievement and knowledge retention across time. Future studies can investigate the usefulness of particular AI solutions, including intelligent tutoring systems and virtual laboratories, in other fields of science and educational stages.

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