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Development and Validation of AI instructional Platform Using ADDIE Model for Enhancing Pre-service Biology Teachers Learning Outcomes in Collaborative Learning Settings in North-East, Nigeria

Abubakar Mallam Aliyu

abuali3531@gmail.com

Air Force Institute of Technology

Amosu Ishiaka Gambari

Federal University of Technology

Isma'il Muhammad Bello

Federal University of Technology

Taliha Abiodun Folorunso

Federal University of Technology

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Abstract

The increasing adoption of Artificial Intelligence (AI) in education presents opportunities for improving personalized learning, learner engagement, and collaborative knowledge construction. However, limited empirical evidence exists on how AI-supported collaborative learning environments can be systematically developed and pedagogically integrated to improve subject-specific learning outcomes. This study developed and validated an AI instructional platform using the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) instructional design model to enhance Biology learning outcomes among pre-service teachers. The study adopted a developmental research design for platform development and a quasi-experimental pretest-posttest non-equivalent control group design to evaluate effectiveness. A sample of 361 Biology pre-service teachers from four Federal Colleges of Education in North-East Nigeria participated in the study. Data were collected using a Genetics Achievement Test and expert validation checklist, and analysed using Content Validity Index (CVI), descriptive statistics, Analysis of Covariance (ANCOVA) and Sidak post hoc multiple comparison test. Findings revealed that the developed platform demonstrated excellent validity in content, instructional suitability, usability, and functionality, with an overall CVI of 0.97. Furthermore, Biology pre-service teachers exposed to the AI instructional platform integrated with think-pair-share, jigsaw and peer tutoring strategies achieved significantly higher academic achievement than those taught using conventional methods $F(3.\ 356) = 11.368$, $p = .01$), $\eta p2 = .087$. Peer tutoring strategy shows highest level of academic achievement which significantly outperformed other groups with a mean difference of 10.567 ($p = .000$). The findings provide implications for teacher education institutions seeking responsible and evidence-based AI adoption in teaching and learning.

Introduction

The integration of Artificial Intelligence (AI) into education represents a significant transformation in teaching and learning practices compared with conventional instructional methods. Unlike conventional approaches that often rely on uniform content delivery, AI-supported learning environments emphasize learner autonomy and responsiveness to individual learning needs. Through features such as real-time feedback, adaptive instructional pathways, and flexible learning progression, AI enables students to engage with learning materials at their own pace. These capabilities enhance learner engagement, support personalized learning experiences, and promote meaningful collaboration, thereby contributing to improved learning outcomes across diverse educational contexts (Chen et al., 2020). Nevertheless, effective teaching and learning remain inherently social processes that depend on interaction, cooperation, and the exchange of ideas among learners to achieve shared educational goals.

Collaborative learning emphasizes the co-construction of knowledge through social interaction and active engagement among learners. This instructional approach involves activities such as discussion, dialogue, peer interaction, and joint problem-solving, which collectively foster the development of higher-order cognitive skills, including critical thinking, reasoning, and knowledge application (Jha, 2023). In virtual learning environments, collaborative learning extends beyond the boundaries of the traditional

classroom by leveraging digital technologies to facilitate communication and teamwork. However, designing virtual collaborative learning environments in which AI functions as a supportive tool that enhances, rather than replaces, meaningful social interaction and peer engagement remains a significant challenge (Sirghi et al., 2024). Consequently, there is an increasing need to develop AI-supported collaborative learning environments that effectively balance technological innovation with collaborative pedagogical practices.

Biology is a fundamental science subject that contributes significantly to scientific advancement and serves as a foundation for understanding the structure, functions, and interactions of living organisms. As a core science discipline, Biology equips learners with the knowledge and skills necessary to understand biological systems and their interactions with the environment. However, many Biology concepts are abstract, complex, and difficult for learners to understand through conventional teaching methods. Topics such as genetics, cell division, molecular biology, ecology, and physiological processes often require visualization, active engagement, and collaborative problem-solving to facilitate meaningful learning. Consequently, many learners experience difficulties in conceptual understanding, knowledge retention, and academic achievement in Biology. These challenges highlight the need for innovative instructional approaches that promote active participation, personalized learning, and collaborative knowledge construction. The integration of Artificial Intelligence (AI) into collaborative learning environments offers opportunities to address these challenges by providing adaptive support, immediate feedback, personalized learning pathways, and interactive learning experiences. Such integration has the potential to enhance Biology learning outcomes by improving learners' understanding of complex biological concepts while fostering collaboration, critical thinking, and problem-solving skills.

Addressing these challenges requires the development of AI-supported collaborative learning platforms grounded in a systematic and theory-informed instructional design framework. The ADDIE instructional design model, comprising Analysis, Design, Development, Implementation, and Evaluation, provides a structured and iterative approach for aligning technological development with pedagogical objectives. Through the application of the ADDIE model, AI-driven features such as intelligent group formation, adaptive scaffolding, visual feedback mechanisms, and learning analytics can be purposefully integrated to support collaborative learning processes. This systematic integration enables AI to reduce educators' administrative and analytical workload while allowing them to focus more effectively on facilitating learner interaction, monitoring collaborative activities, and providing instructional support (Luan et al., 2020). Consequently, learners benefit from a more engaging, equitable, and supportive collaborative learning environment. By ensuring that technological innovation remains closely aligned with instructional objectives and collaborative pedagogy, the ADDIE model provides a robust framework for developing AI-supported collaborative learning platforms capable of enhancing Biology learning outcomes.

Despite the growing adoption of Artificial Intelligence technologies in education, empirical evidence regarding the systematic development and evaluation of AI-supported collaborative learning platforms specifically designed to enhance Biology learning outcomes remains limited. Although previous studies

have examined the application of AI in education and its effectiveness in virtual collaborative learning, relatively few have focused on integrating AI-supported collaborative learning with a structured instructional design framework such as the ADDIE model for teaching complex Biology concepts, particularly genetics, among pre-service teachers. This gap limits understanding of how instructional design principles can guide the development of AI-supported collaborative learning environments that effectively promote meaningful learning and academic achievement in Biology. Therefore, this study seeks to develop and evaluate an AI-supported collaborative learning platform using the ADDIE instructional design model to enhance Biology learning outcomes among pre-service teachers.

Problem Statement

Genetics is a fundamental area of Biology that explains the principles of heredity and variation and provides a foundation for understanding many biological concepts. Despite its importance, genetics remains one of the most challenging topics for Biology pre-service teachers because many of its concepts are abstract, conceptually demanding, and difficult to visualize through conventional instructional approaches. Consequently, many pre-service Biology teachers develop misconceptions and demonstrate low academic achievement in genetics. These persistent learning difficulties underscore the need for more effective instructional approaches capable of promoting meaningful understanding and improving learning outcomes in genetics.

Collaborative learning has been widely recognized as an effective instructional approach for enhancing learner engagement, promoting active learning, and improving academic achievement. The emergence of virtual collaborative learning has further expanded the opportunities for interaction, communication, and knowledge sharing through digital technologies. However, the effective implementation of virtual collaborative learning for teaching and learning genetics remains challenging. Teachers often encounter difficulties in organizing collaborative groups, monitoring learner participation and engagement, assessing collaborative activities, providing timely feedback, and addressing individual learning differences in online learning environments. As a result, learners may experience reduced participation, ineffective collaboration, and persistent difficulties in understanding complex genetic concepts, which contribute to poor academic achievement.

The integration of Artificial Intelligence (AI) into virtual collaborative learning platforms offers a great potential to enhance teaching and learning. It occurs through personalized learning pathways, intelligent tutoring, adaptive feedback, automated group formation, and learning analytics. Despite these capabilities, many existing collaborative learning platforms provide limited AI support for facilitating collaborative learning activities, personalizing instruction, and addressing learners' conceptual difficulties in genetics. Although numerous studies have explored the application of AI in education and its effectiveness in virtual collaborative learning, relatively few have focused on the systematic development and evaluation of AI-supported collaborative learning platforms using a structured instructional design framework such as the ADDIE model for teaching genetics among pre-service Biology teachers. Consequently, there remains limited empirical evidence regarding how AI-supported

collaborative learning platforms can be systematically designed and implemented to improve genetics learning outcomes within collaborative learning environments. Therefore, there is a need to develop and evaluate AI-supported collaborative learning platform based on ADDIE instructional design model to enhance the learning outcomes of pre-service Biology teachers in genetics.

Objectives

The study “developed and validate an AI instructional platform using ADDIE model for enhancing pre-service Biology teachers learning outcomes in collaborative learning settings in North-East, Nigeria”, while the specific objectives are to;

1. develop an AI instructional platform using the ADDIE model.
2. Validate an AI instructional platform to determine its content validity, instructional suitability, usability, and functionality before implementation.
3. determine the effect of AI instructional platform integrated with the think-pair-share, jigsaw and peer tutoring strategy on the academic achievement of pre-service Biology teachers in North-East, Nigeria.

Research Questions

The following research questions were raised to guide the study;

1. What are the processes involved in development of AI instructional platform using ADDIE model?
2. To what extent does AI instructional platform valid in terms of content, instructional suitability, usability, and functionality as evaluated by experts?
3. What is the effect of AI instructional platform integrated with think-pair-share, jigsaw and peer tutoring strategies on the academic achievement of pre-service Biology teachers taught genetics compared with those taught using conventional teaching method in North-East, Nigeria?

Research Hypothesis

The following null hypotheses were formulated and tested at 0.05 level of significance.

1. There is no significant difference in achievement scores of pre-service Biology teachers taught genetics with AI instructional platform using think-pair-share, Jigsaw, and peer tutoring strategies and those taught using conventional teaching method in Colleges of Education, North-East, Nigeria.

Literature Review

Artificial intelligence collaborative learning platform in education

Artificial intelligence collaborative learning platforms are online tools that leverage AI to facilitate collaborative learning experiences. These platforms use AI to analyze the performance and engagement of learners. It provides personalized recommendations and enables real-time collaboration and communication among learners. Through the use of machine learning algorithms, these platforms can offer adaptive learning experiences, identify individual learning gaps and suggest customized learning paths (Gligorea et al., 2021).

Additionally, it can promote peer interaction, group projects, and cooperative problem-solving through intelligent grouping and interactive features (Tan et al., 2022). By integrating AI technology into collaborative learning, the platform will possess all the potential to enhance the overall learning experience by fostering collaboration, personalization, and engagement among learners. They introduced an adaptive learning platform that tracks students' academic performance and recommends interventions to support those at risk of dropping out. The adaptive learning platform uses AI to analyze past student data and identify those at risk of dropping out. Automatic nudges are then sent to current students who are facing similar challenges. These students are then connected to tutors, advisors, or other support services to help them recover. Over the past ten years, GSU's adaptive learning supports have increased its graduation rate by more than 20% (Rivera et al., 2022).

Artificial intelligence (AI) is rapidly transforming the way we teach and learn. These AI learning tools are being used to provide students with course materials, immediate feedback, and personalized instruction (Dai et al., 2023). This can assist students in learning faster and better understanding the concepts they are learning (Al-Ka'bi, 2023). AI helps students to learn more effectively, and efficiently and at the same time improve their academic performance through personalized learning (Hanaysha et al., 2023). AI can also help students to develop skills such as critical thinking and problem-solving skills. It creates a conducive learning environment where students can work together to solve problems and develop projects (Alfalah, 2023). It is possible that ChatGPT if properly used with careful planning, would present language teachers with a vast opportunity to enrich their lessons and provide students with a more interesting and engaging learning environment (Zhai, 2022).

Artificial intelligence platforms have the potential to improve education by personalizing and customizing students' learning experiences in a way that can improve students' academic performance and overall comprehension of knowledge (Salido, 2023). Mercier et al. (2023) mentioned that collaborative learning platforms enhance the performance of higher education students. Nasir and Khan (2020) also stated that online collaboration learning enhances university students' performance and satisfaction helps them retain learning content without difficulties. According to the study conducted by Dantas et al. (2022), the performance of students using AI-based collaborative learning platforms was raised by up to 200%, compared to the students taught using teacher-centered learning methods. Hande further lamented that AI-based learning platforms complement classroom instruction and accelerate learning for all learners by offering personalized guidance that responds to the changing needs of learners.

Using online collaborative platforms among postgraduate students gives them room to constantly interact with peers and with the lecturer without disturbing them in their places of assignments. Online collaborative learning groups are more active, meeting regularly for discussions, sharing knowledge among them and enhancing their entire research activities (Ajayi and Ajayi, 2020). AI-based tutoring systems increase student's engagement and motivate them through the use of gamification and immediate feedback from the system. Engagement is a critical factor in effective learning; therefore, AI-enabled educational platforms should have a positive impact on student engagement and achievement.

In addition to general customization and automated nudges, recent developments in educational technology are increasingly concentrating on AI-powered orchestration tools that specifically enhance peer-to-peer interactions. Conventional online collaborative settings frequently experience issues with passive participation and uneven involvement, stemming from simplistic group formation methods. To address this, automated grouping algorithms utilize machine learning to dynamically organize learners based on their cognitive styles, personality characteristics, or foundational knowledge, leading to more equitable and effective collaborative groups. Moreover, within these intelligently assembled teams, the incorporation of real-time co-authoring tools combined with adaptive generative AI agents offers support during active knowledge creation. These AI agents function as automated facilitators overseeing shared workspaces, recommending structural enhancements during live note-taking, and providing contextual prompts that encourage more profound discussions. By integrating AI directly into the collaborative process rather than considering it just as a standalone tutor, virtual learning environments can greatly improve collective problem-solving, maintain student engagement, and ultimately achieve better academic outcomes.

Theoretical Framework

This study is anchored on Constructivist Learning Theory, Social Constructivist Theory, the Technological Pedagogical Content Knowledge (TPACK) Framework, and the ADDIE Instructional Design Model. These theoretical perspectives collectively provide a foundation for understanding how artificial intelligence (AI) can be integrated into collaborative learning environments to support meaningful knowledge construction and improve Biology learning outcomes.

Theoretical Integration

The integration of these theoretical perspectives provides a comprehensive explanation of how the AI-supported collaborative learning platform influences Biology learning outcomes. Constructivist theory explains the individual process of knowledge construction through active engagement with learning resources, while social constructivist theory explains how collaboration, interaction, and peer learning contribute to shared knowledge development. The TPACK framework explains how AI technology can be effectively combined with collaborative pedagogy and Biology content to create meaningful learning experiences. The ADDIE model provides the systematic approach for designing, implementing, and evaluating the platform.

Methodology

This study adopted a developmental research design for the development of AI instructional platform and was guided by ADDIE model, and quasi-experimental pretest-posttest non-equivalent control group design to determine its effectiveness on pre-service Biology teachers. The study was conducted in North-East, Nigeria using four (4) Colleges of Education (Federal College of Education (Tech) Potiskum, Federal College of Education (Tech) Gombe, Federal College of Education Jama'are and Federal College of Education Yola). These institutions were selected because they offer Biology Education programme and has adequate facilities for the implementing of developed AI instructional platform. The population of the study comprised of two thousand five hundred and sixty-three (2563) pre-service Biology teachers in Colleges of Education in North-East, Nigeria. A multistage sampling procedure was uses to determine the sample. In the first stage, the four (4) colleges were selected using cluster sampling techniques, while in the second stage, an intact classes of pre-service Biology teachers were used. The sample size consisted of three hundred and sixty-one (361) pre-service Biology teachers from the selected institutions. The intact class were randomly assigned to the treatment and control groups.

The AI instructional platform was developed following the five phases of the ADDIE model. During the Analysis phase, learners' characteristics, instructional needs, curriculum requirements, and technological requirements were identified. The Design phase involved developing instructional objectives, learning contents, collaborative learning activities, assessment strategies, user interface layouts, and AI-supported instructional features. During the Development phase, the platform was programmed and integrated with genetics learning contents, collaborative discussion forums, quizzes, AI-assisted feedback mechanisms, learner analytics, and progress monitoring features. The Implementation phase involved deploying the platform for instructional delivery among participants in the experimental group, while Evaluation phase focused on determining the platform's usability, functionality, instructional suitability, and effectiveness in improving Biology learning outcomes. Before implementation, the developed platform was subjected to expert validation to determine its content validity, instructional suitability, usability, and functionality. Three experts comprising specialists in Educational Technology, Computer Science, and English Education evaluated the platform using a structured validation checklist based on a four-point rating scale ranging from 1 (Not Relevant) to 4 (Highly Relevant). The Item-level Content Validity Index (I-CVI) and Scale-level Content Validity Index based on the average method (S-CVI/Ave) were computed to establish the validity of the platform. Following the recommendations of Lynn (1986) and Polit and Beck (2006), an I-CVI value of .78 or above and an S-CVI/Ave value of .90 or above were considered evidence of acceptable and excellent content validity. Comments and recommendations provided by the experts were incorporated into the final version of the platform before implementation.

Data were collected using Genetics Achievement Test (GAT). The GAT consisted of two sections: Section A consist of demographic data of the respondents, while Section B comprised of fifty multiple-choice items covering genetics concepts. The instrument was also validated by experts to establish its content and face validity. The reliability of the GAT was established using test-retest method and Pearson

Product Moment Correlation Coefficient (PPMCC) was used and yielded a reliability coefficient of 0.82. Prior to the treatment, GAT was administered as a pretest to both experimental and control groups to determine their initial level of academic achievement. The experimental groups were subsequently taught genetics using AI instructional platform integrated with think-pair-share, jigsaw and peer tutoring strategies, while the control group received instruction using conventional teaching method. The treatment lasted for twelve weeks, after which GAT was re-administered as a posttest to both groups to determine the effect of the intervention on academic achievement. Data were analysed using Statistical Package for the Social Sciences (SPSS). Mean and standard deviation were used to answer the research question, while the Item-level Content Validity Index (I-CVI) and Scale-level Content Validity Index (S-CVI/Ave) were used to determine the validity of the developed platform. Analysis of Covariance (ANCOVA) was also used to test the hypotheses and Sidak post hoc multiple comparison test at 0.05 level of significance.

Result

Research Question One: What are the processes involved in the development of AI instructional platform using ADDIE model? The AI instructional platform was developed using ADDIE model. The model provides a systematic framework comprising five interrelated phases: Analysis, Design, Development, Implementation, and Evaluation. Figure 4.1 present the illustration of the developmental life cycle of the AI instructional platform.

Figure 4.1 Software Development Life Cycle (ADDIE Model)

Development Procedure of the AI Instructional Platform Using the ADDIE Model.

The AI instructional platform was developed through a systematic and iterative instructional design process guided by the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. The ADDIE framework provided a structured approach for integrating pedagogical principles with modern software engineering practices to produce a platform that supports collaborative learning, enhances student engagement, and improves learning outcomes in Biology. Throughout the development process, Agile software development techniques were integrated within the ADDIE framework to facilitate continuous refinement, testing, and improvement of the platform.

Analysis Phase

The first phase involved a comprehensive needs assessment to establish the instructional and technical requirements of the platform. The biology curriculum was carefully reviewed to identify difficult concepts requiring collaborative learning support. Existing teaching approaches and digital learning tools were examined to determine gaps that limited effective collaboration among pre-service biology teachers. The analysis further identified the instructional requirements for implementing collaborative learning strategies and integrating artificial intelligence into classroom activities.

Learner characteristics, instructional objectives, technological infrastructure, and system requirements were also analyzed. Particular attention was given to identifying requirements for monitoring learner engagement, analyzing learning performance, and generating intelligent instructional support through AI assistant. The outcome of this phase was a comprehensive requirements specification that served as the foundation for the subsequent stages of development.

Design Phase

Based on the findings from the analysis phase, the platform architecture and instructional framework were designed. A detailed blueprint of the system was prepared, specifying the organization of learning activities, user interactions, database structure, and communication workflow. User interface wireframes was developed to ensure that both teachers and students can easily navigate the platform.

The instructional design incorporated collaborative learning activities that encouraged interaction among learners while enabling the AI assistant to provide intelligent prompts, learning guidance, and immediate instructional support. The database schema, system navigation, user roles, authentication procedures, assessment modules, and analytics components were also designed during this phase. This stage produced a complete instructional and technical design that guided software development.

Development Phase

The development phase transformed the design specifications into a fully functional AI-supported collaborative learning platform. Agile software development methodology was employed, allowing the system to be developed incrementally through iterative development cycles. Each development cycle focused on implementing specific platform features while continuously testing and refining system performance.

The backend of the platform was developed using Node.js and Express, while the frontend interface was implemented using React and TypeScript. A PostgreSQL relational database managed student records, learning activities, assessments, and platform analytics. Authentication and authorization mechanisms were implemented using JSON Web Token (JWT) technology with Role-Based Access Control (RBAC) to ensure secure access for teachers and students.

Several functional modules were developed during this stage, including classroom management, student enrolment, quiz management, automated pre-test and post-test administration, AI-assisted instructional support, collaborative note sharing, and real-time communication. Google Gemini API was integrated to provide intelligent educational prompts and facilitate learner interaction during collaborative activities. Socket.io enabled real-time communication among participants, while Jitsi video conferencing supported synchronous collaborative discussions. Additional cloud storage facilities were incorporated for managing instructional resources, including PDF documents, Word files, and multimedia materials.

To support research objectives, an analytics engine was integrated into the platform to monitor learner participation, interaction frequency, collaboration patterns, assessment performance, and overall

learning progress. Performance optimization and user interface improvements were continuously implemented throughout the development process to improve usability and system responsiveness.

Implementation Phase

Following successful development, the platform was deployed within the experimental learning environment for classroom implementation. Teachers received orientation and training on platform operation, classroom management features, and methods for facilitating AI-supported collaborative learning activities.

Students were enrolled through the platform management system and assigned to their respective collaborative learning groups. Learning sessions were conducted using structured collaborative strategies, while the AI assistant provided real-time instructional guidance, learning prompts, and collaborative support throughout classroom activities. During implementation, the platform facilitated classroom interaction, resource sharing, online discussions, collaborative note-taking, assessment administration, and continuous monitoring of learner participation.

The implementation phase ensured that, all instructional components functioned effectively within authentic classroom settings and provided learners with an interactive collaborative learning experience.

Evaluation Phase

The final stage involved comprehensive evaluation of both the technical performance and educational effectiveness of the platform. Evaluation was conducted at both formative and summative levels to ensure continuous improvement and determine the overall success of the platform.

Formative evaluation occurred throughout development using unit testing, component testing, and integration testing to verify the correctness of individual software modules, user interface components, and communication between system components. Integration testing specifically examined interactions between the AI engine, database, and real-time collaborative features. Summative evaluation was conducted after deployment through user acceptance testing involving teachers to determine the usability and functionality of the platform within actual classroom environments. Performance stress testing was also performed to evaluate system stability under multiple simultaneous users, while security validation ensured the integrity of uploaded files, authentication procedures, and communication channels.

Beyond technical evaluation, the platform generated research-based evidence by automatically scoring pre-test and post-test assessments, monitoring learner engagement, tracking collaborative interactions, and analyzing student performance. Statistical analyses were conducted on learning outcomes and engagement indicators to determine the effectiveness of the AI-supported collaborative learning platform.

Several technical challenges emerged during development, including conflicts arising from simultaneous collaborative note editing, delays in AI response generation, database query performance, and browser

compatibility issues. These challenges were addressed through operational transformation algorithms, response caching techniques, database optimization using materialized views, and implementation of WebRTC adapters to improve compatibility across multiple browsers,

Research Question Two

To what extent does AI instructional platform valid in terms of content, instructional suitability, usability, and functionality as evaluated by experts?

Table 1
Content Validity Index of AI Instructional Platform

Validation Domain	No of Items	Mean I-CVI	S-CVI/AVE	Interpretation
Content Validity	12	0.97	0.98	Excellent
Instructional Suitability	10	0.96	0.97	Excellent
Usability	8	0.95	0.96	Excellent
Functionality	10	0.98	0.98	Excellent
Overall Scale	**40**	**0.97**	**0.97**	**Excellent**

Table 1 present the content validity index (CVI) of the AI-supported collaborative learning platform as evaluated by experts. The findings show that, the platform demonstrated an excellent validity index across all four domains. The mean item level of the content validity index (I-CVI) ranged from 0.95–0.98. while the scale level content validity index (S-CVI) ranged from 0.96–0.98. The overall I-CVI and S-CVI/AVE value is 0.97 which exceeded the benchmark value. This indicates a high level of agreement among the experts. Based on the expert's recommendation, a minor revision was made to improve the platform before implementation. Therefore, the AI platform was considered valid and suitable for use in teaching biology pre-service teachers.

Research Question 3

What is the effect of AI instructional platform integrated with think-pair-share, jigsaw and peer tutoring strategies on academic achievement of pre-service Biology teachers compared to those taught using conventional teaching method?

Table 2
Mean and Standard Deviation of Pretest and Posttest of the Academic Achievement scores of Pre-service Biology Teachers taught Genetics using AI instructional platform integrated with Think-Pair-Share, Jigsaw and Peer Tutoring and those taught with Conventional Method

Group		Pre-test		Post-test		Mean Gain
	N	Mean	SD	Mean	SD	
Think Pair Share	86	20.03	9.05	63.23	12.18	42.87
Jigsaw	94	23.64	8.96	58.33	14.31	34.69
Peer Tutoring	74	21.18	9.21	55.15	11.04	33.97
Conventional	107	20.03	8.18	48.70	16.73	28.67

Table 2 indicates the pretest and posttests mean scores, standard deviation and mean gain of biology pre-service teachers taught with AI-collaborative learning strategies and those taught using conventional teaching method. All the four groups show improvement in the mean scores after the intervention. AI collaborative learning platform group integrated with think-pair-share recorded the highest mean scores and standard deviation of (M = 63.23, SD = 12.18) with a highest mean gain of 42.87. AI supported jigsaw group had a mean score and standard deviation of (M = 58.33, SD = 14.31) with mean gain of 34.69. AI supported peer tutoring group maintained a mean score and standard deviation of (M = 55.15, SD = 11.04) and a mean gain of 33.97. The conventional teaching method group recorded the lowest mean score and standard deviation of (M = 48.70, SD = 16.73) with mean gain of 28.67. These implies that, AI-supported collaborative learning platform improved academic achievement of pre-service Biology teachers more than the conventional teaching method. Think-pair-share improved academic achievement more than other collaborative and conventional method.

Hypothesis Testing

Hypothesis One

There is no significant difference in achievement scores of pre-service Biology teachers taught genetics with AI instructional platform using think-pair-share, Jigsaw, and peer tutoring strategies and those taught using conventional teaching method in Colleges of Education, North-East, Nigeria. To test this hypothesis, Analysis of Co-variance (ANCOVA) was used and the result was presented in Table 3.

Table 3
ANCOVA Results of the Academic Achievement Between Pre-Service Biology Teachers taught with AI Instructional Platform Using Think-pair-share, Jigsaw, Peer Tutoring Strategies and Conventional Teaching Method

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	19737.771[a]	4	4934.443	30.901	.000	.258
Intercept	69092.494	1	69092.494	432.682	.000	.549
Pretest	12064.725	1	12064.725	75.554	.000	.175
Group	5445.962	3	1815.321	11.368	.000	.087
Error	56847.553	356	159.684			
Total	964346.000	361				
Corrected Total	76585.324	360				
a. R Squared = .258 (Adjusted R Squared = .249)						

Table 4.9a indicates that the differences in the scores of the pre-service Biology teachers in the four instructional groups are significant, F (3. 356) = 11.368, p = .01), ηp2 = .087. This indicates a statistically significant difference in the academic achievement score of pre-service Biology teachers taught genetics with AI instructional platform using think-pair-share, jigsaw, peer tutoring strategies and those taught using conventional method. Therefore, null hypothesis was rejected. As a follow-up, a Sidak post-hoc multiple comparison test was conducted to determine the direction of the existing difference between the instructional groups. Table 4.10b presents the result.

Table 4.9
b: Sidak Post-hoc Multiple Comparisons of Mean Academic Achievement Between Pre-Service Biology Teachers taught with AI Instructional Platform using think-pair-share, Jigsaw and Peer Tutoring and those taught using Conventional Teaching Method

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]
Think-Pair-Share	Jigsaw	-2.697	1.898	.639
	Peer Tutoring	-5.818	2.006	.023
	Conventional	4.749	1.831	.041
Jigsaw	Think-pair-share	2.697	1.898	.639
	Peer Tutoring	-3.121	1.968	.515
	Conventional	7.446	1.806	.000
Peer Tutoring	Think-pair-share	5.818	2.006	.023
	Jigsaw	3.121	1.968	.515
	Conventional	10.567	1.915	.000
Conventional	Think-pair-share	-4.749	1.831	.041
	Jigsaw	-7.446	1.806	.000
	Peer Tutoring	-10.567	1.915	.000

The findings revealed that, pre-service Biology teachers taught using peer tutoring strategy shows highest level of academic achievement which significantly outperformed those taught using conventional group with a substantial mean difference of 10.567 (p = .000). The Jigsaw group recorded a significant improvement in the academic achievement scores than those in the conventional group, with a mean difference of 7.446 (p = .000). Think-pair-share group also performed significantly better than those in the conventional group, with a mean difference of 4.749 (p = .041). However, there was no statistically significant difference between the Jigsaw and think-pair-share groups (p = .639), nor between the peer tutoring and jigsaw groups (p = .515). This implies that, pre-service biology teachers taught using peer tutoring strategy show the highest level of academic achievement which significantly outperformed those taught using conventional teaching method.

Discussion of Findings

Development of AI Instructional Platform Through the ADDIE Framework

The development of AI-supported collaborative learning platform is an additional contribution to the field of artificial intelligence in education. This demonstrated how technology can be systematically integrated in to instructional design principles. The finding stated that, the platform was successfully

developed using five phases of ADDIE instructional model (Analysis, Design, Development, Implementation, and Evaluation) indicates how effective AI was integrated in to education. The integration of AI requires more than technological innovation, it also includes deliberate alignment between learner characteristics, pedagogical objectives, instructional strategies, and technological capabilities. The finding was inline with Ouyang and Jiao (2021) stated that, integration of artificial intelligence (AI) into educational systems should be guided by theoretically informed instructional frameworks to ensure technological affordances are effectively transformed into meaningful learning experiences.

The successful application of ADDIE framework in this study is important because many AI-supported learning platforms have focused on evaluating the platform rather than logical documentation of the process through such platforms are designed and developed. The present study expands the existing literature by documenting the pathway for developing an AI-collaborative learning environment specifically for Biology teacher. Through the Analysis phase, learner characteristics, curriculum demands, technological requirements, and instructional challenges associated with Biology learning were identified. This approach ensured that the developed platform addressed real educational needs rather than providing technology-driven solution without pedagogical justification. Kasneci et al. (2023) asserted that AI applications can only create meaningful educational value when they are designed intentionally to address specific learning challenges and are embedded within appropriate pedagogical contexts.

The finding provides empirical support for the continued relevance of ADDIE instructional design model in guiding the integration of AI into education. Although AI technologies such as intelligent tutoring systems, generative AI, and learning analytics offer new opportunities for enhancing learning, their effectiveness depends on systematic planning, pedagogical alignment, and continuous evaluation. The developed platform showed how AI functionalities, such as adaptive feedback, learner analytics, collaborative communication, and intelligent instructional support, can be integrated into learning environment. Holmes et al., (2022). AI implementation should be extended beyond technological tools but rather focus on meaningful pedagogical integration to solve learning needs. Furthermore, the development process aligns with constructivist learning theory by promoting active knowledge construction through interaction with learning resources, adaptive support, collaboration, and learner engagement. Rather than positioning learners as passive recipients of AI generated content. AI-enhanced learning environments should facilitate active learning and enhance engagement rather than automate knowledge delivery (Tlili et al., 2023).

Furthermore, the integration of AI into collaborative learning platforms show the relevance of social constructivist theory in digital learning environments. Vygotsky's social constructivist reported that, learning occurs through interaction, dialogue, and collaboration with peers. In this study, AI functioned as a mediating tool that supported peer interaction, provided instructional prompts, and enhanced collaborative problem-solving. This shows that, AI does not diminish social constructivist view but rather strengthened the processes by providing additional support to prove it existence. Ouyang and Jiao

(2021) argued that the future of educational AI does not lie in replacing human interaction but in augmenting the capabilities of teachers and learners through intelligent assistance.

The significance of this finding goes beyond technical development of a platform. It shows that, the integration of AI into Biology education requires a balance between technology and pedagogy. Biology contains several abstract concepts, including genetics, molecular processes, and physiological mechanisms, which require visualization, explanation, and conceptual linking between theories and practical. Therefore, designing such platform for Biology learning required subject-specific instructional strategies and learning resources. This supports the findings of Chen et al., (2020) reported that, future AI educational research should increasingly move toward domain-specific intelligent learning environments rather than generalized AI applications.

Validation and Pedagogical Quality of the Developed AI Instructional Platform

The second major finding of this study revealed that, developed AI instructional achieved excellent validation outcomes across content validity, instructional suitability, usability, and functionality. The high content validity index values obtained from expert evaluation show that, the platform possessed strong pedagogical and technical qualities for implementation in Biology education. This was justified due to the systematic evaluation process the platform subjected to before real classroom deplayment. The excellent validity ratings show that, the platform successfully achieved alignment between technological features and instructional requirements. This finding is supported by Crompton and Burke (2023) reported that the effectiveness of educational technologies depends not only on their technical sophistication but also on pedagogical appropriateness, usability, and alignment with curriculum objectives.

The high content validity and excellent instructional suitability ratings indicate that the platform captured the intended Biology learning objectives by incorporating relevant instructional resources and aligning them with principles of effective learning. Content validity is important because oversimplification of scientific concepts may reinforce misconceptions rather than enhance understanding. The expert agreement observed in this study shows that the biology content embedded within the platform was appropriate and supported meaningful learning among pre-service teachers. This finding aligns with the argument of Kasneci et al. (2023) that AI applications in education require domain-specific knowledge integration to ensure scientifically accurate and instructionally relevant support. Furthermore, the platform's alignment with collaborative learning principles through activities that promoted interaction, peer explanation, discussion, and shared problem-solving reflects the importance of embedding educational technologies within active learning pedagogies. Bond et al., (2021) reported that technology-enhanced learning environments are more effective when they complement established instructional approaches rather than merely emphasizing technological features.

The usability and functionality ratings provide evidence of the practical feasibility and effectiveness of implementing the platform in real educational settings. Usability is a critical factor in technology

adoption because teachers and learners are less likely to engage with systems that are difficult to navigate, complex to operate, or poorly aligned with classroom practices. The findings suggest that the platform provided an accessible, user-friendly, and effective learning environment while successfully integrating key components such as collaborative learning tools, AI-assisted feedback mechanisms, assessment features, and learner monitoring functions. This supports the Technology Acceptance Model, which identifies perceived ease of use and perceived usefulness as major determinants of users' willingness to adopt educational technologies (Davis, 1989). Similarly, Chiu et al., (2023) reported that usability, trust, and perceived educational value are important predictors of successful AI integration in education. Furthermore, the positive functionality evaluation highlights the importance of technical reliability and operational effectiveness in AI-supported learning environments, where system failures, inaccurate responses, or poor component integration may undermine user experience and learning outcomes. This finding is inline with Xu and Ouyang (2022) reported that educational AI platforms should be evaluated not only based on learning outcomes but also on their technical performance and functional reliability.

The validation results further reinforce the importance of multidisciplinary collaboration in developing AI-supported educational platforms. The involvement of experts from educational technology, measurement and evaluation, and related educational fields ensured that the platform was assessed from both technological and pedagogical perspectives. This approach reflects current recommendations in AI education research that successful educational AI development requires collaboration between computer scientists, educators, instructional designers, and subject specialists (Zawacki-Richter et al., 2019). Such collaboration helps prevent the development of technically advanced systems that lack educational relevance.

Effectiveness of AI Instructional Platform Integrated with Think-Pair-Share, Jigsaw and Peer Tutoring Strategies on Pre-service Biology Teachers Academic Achievement

The findings revealed that, AI instructional platform integrated with think-pair-share, jigsaw, and peer tutoring significantly improved the academic achievement of pre-service Biology teachers compared to those taught using conventional teaching method. Among the strategies, peer tutoring yielded the highest academic achievement, followed by jigsaw and think-pair-share, all of which outperformed the conventional method. These findings are consistent with the findings of Maanu, et al., (2025) which found that, pre-service teachers exposed to AI-assisted collaborative instruction had significantly higher academic achievement than their counterparts who received instruction using conventional teaching method. Another research revealed that, collaborative instructional settings integrated with AI tools facilitate shared metacognition and cognitive engagement, which contribute to higher learning outcomes (Iqlab et al., 2025).

A study conducted by Shulgina et al., (2025) proves that, integrating AI into collaborative learning environments, particularly peer tutoring, significantly enhances academic achievement compared to conventional teaching methods. Another study showed that, AI-supported learning platform integrated

with peer tutoring instructional strategy, provides targeted audience with personalized feedback, and structured interaction which improves comprehension, and overall learning outcome (Weijers et al., 2025). Similarly, Lee et al., (2024) reported that, AI-mediated collaborative learning platform, integrated with jigsaw enhanced group interactions, improved both pedagogical and content knowledge which in turn improved academic achievement among pre-service teachers. In contrary to the finding, Xu et al., (2025) revealed that, technology-supported collaborative learning sometimes fails to improve academic performance, instead it creates cognitive overload and reduces overall learning outcomes. Another research mentioned that, technology assisted collaboration integrated with AI may not replicate the social and interactive benefits of conventional human collaboration, and in some cases, traditional pair leads to better engagement and improved learning outcome (Fan et al., 2025).

Conclusion

This study developed and validate AI instructional platform using ADDIE model to enhance Biology learning outcomes among pre-service Biology teachers. The findings demonstrated that the platform was systematically developed using Analysis, Design, Development, Implementation, and Evaluation phases. This ensures alignment between technological features, pedagogical objectives, and learners' instructional needs. The developed platform achieved excellent validity in terms of content, instructional suitability, usability, and functionality, confirming its appropriateness for educational implementation. Furthermore, the integration of AI instructional platform with think-pair-share, jigsaw and peer tutoring strategies significantly improved academic achievement of Biology pre-service teachers compared with those taught using conventional teaching methods. Therefore, the study concludes that AI instructional platforms, when developed using systematic instructional design framework and integrated with effective collaborative pedagogy, provide innovative and effective approach for improving Biology learning outcomes and advancing technology-enhanced teacher education.

Recommendations

1. Educational technology developers and teacher education institutions should adopt systematic instructional design frameworks, particularly ADDIE model, when developing AI-supported learning platforms. This is essential in order to ensure alignment between instructional objectives, learner characteristics, curriculum requirements, pedagogical strategies, and technological features.
2. AI-supported educational platforms should undergo comprehensive validation by experts in educational technology, Biology education, measurement and evaluation, and software development before classroom implementation to establish their content validity, instructional suitability, usability, and functionality.
3. Biology educators in teacher education institutions should integrate AI instructional platforms with the peer tutoring strategy when teaching abstract and conceptually demanding topics such as genetics to promote active participation, collaborative knowledge construction, personalised instructional support, and academic achievement.

Declarations

Ethics approval and consent to participate

This study involving human participants was reviewed and approved by the Research Ethics Committee of the four Federal Colleges of Education (Federal College of Education (Tech) Potiskum, Federal College of Education (Tech), Gombe, Federal College of Education Jama’are and Federal College of Education Yola). The Research Ethics Committee operates as the institutional based ethics review body responsible for reviewing and approving studies involving human participants. All procedures were conducted in accordance with relevant institutional guidelines, applicable ethical standards, and the principles of the Declaration of Helsinki.

Informed consent

Informed consent was obtained from all participants prior to data collection. Participants were informed about the purpose of the study, the voluntary nature of their participation, the procedures involved, and the use of their assessment for research purposes. Only participants who provided informed consent were included in the study.

Consent to Publish

Not applicable.

Conflict of Interest

The author(s) declare that they have no competing interests or conflicts of interest related to the publication of this study.

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Author Contribution

1. Abubakar Mallam Aliyu wrote the main manuscript. - Gambari, A. I edited the content and provide design for developing AI instructional platform. Taliha, A. F. Developed the AI instructional platform. - Isma'il, M. B. Provide financial support for the development of the AI instructional platform.

Data availability

The datasets generated and analysed during the current study are not publicly available due to participant confidentiality and ethical restrictions, but are available from the corresponding author on reasonable request.

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Figures

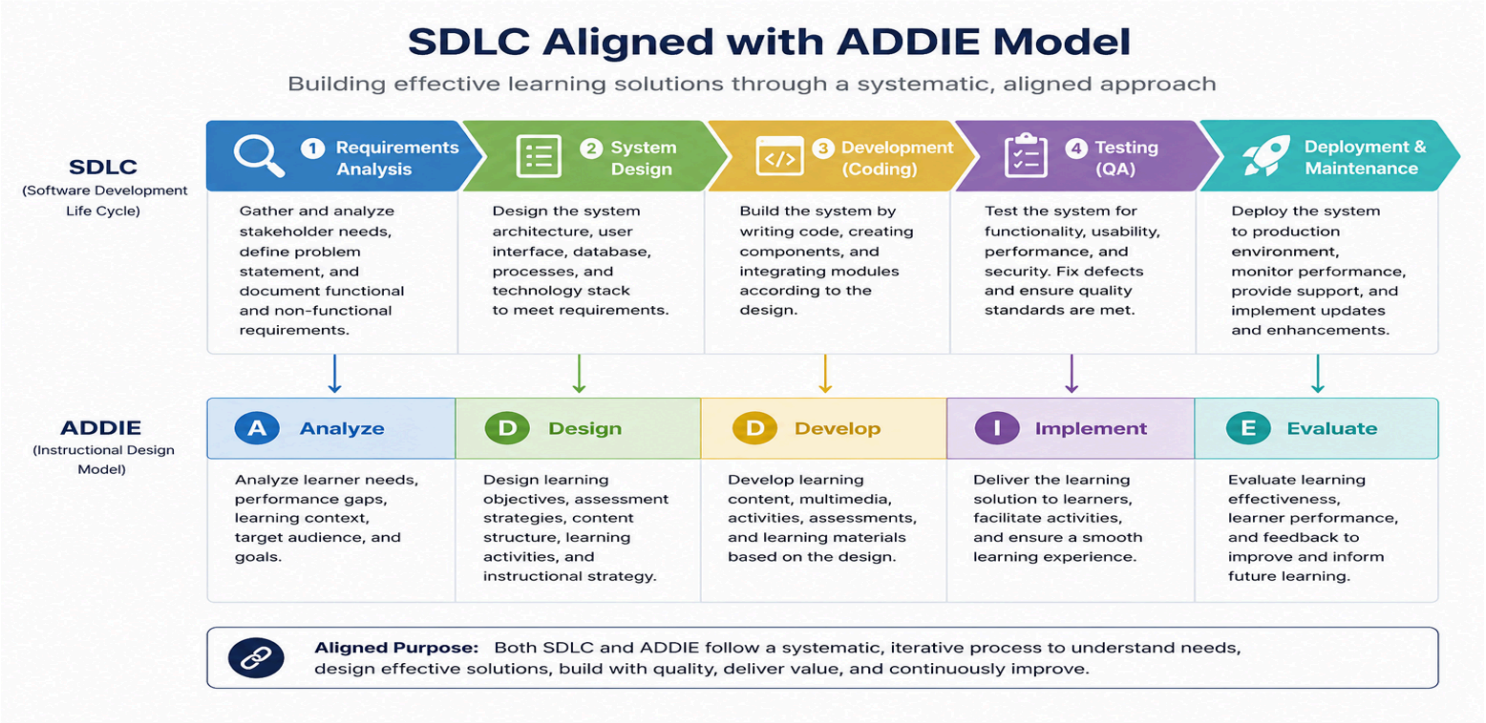


Figure 1

Software Development Life Cycle (ADDIE Model)