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***Correspondence**
Ntegwung, G. J.

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Effects of Ai-assisted Inquiry and Concept Mapping Learning Strategies on Students' Academic Performance and Attitude in Biology in Secondary Schools

Ntegwung G. J.[1], Atabang A. A.[2], Sunday E. S[3] & Edoho B. A.[4]
[1, 2,4]Department of Science Education, Akwa Ibom State University
[3]Department of Science Education, University of Uyo, Uyo, Akwa Ibom State

Abstract

The persistent use of teacher-centred instructional approaches in Biology has continued to limit students' understanding of abstract concepts and the development of positive attitudes toward the subject. This study investigated the effects of AI-assisted inquiry and concept mapping on secondary school students' academic performance and attitudes toward Biology using the concept of cellular respiration. The study adopted a quasi-experimental pretest-posttest non-equivalent control group design. The population comprised all Senior Secondary Two (SS II) Biology students in the study area. Two public secondary schools were selected using simple random sampling. Thereafter, one intact SS II Biology class was selected from each school. The intact classes constituted the sample for the study, giving a total of 87 students. Two instruments were used for data collection: the *Cellular Respiration* Performance Test (CRPT) and the Biology Attitude Scale (BAS). Mean and standard deviation were used to answer the research questions, whereas Analysis of Covariance (ANCOVA) was employed to test the hypotheses at the 0.05 level of significance. The findings revealed that students taught cellular respiration using AI-assisted inquiry learning achieved higher academic performance and developed more positive attitudes toward Biology than those taught using the concept mapping learning strategy. The study further established that the observed differences in students' academic performance and attitudes were statistically significant in favour of AI-assisted inquiry learning. It was concluded that although both instructional strategies enhanced students' learning outcomes, AI-assisted inquiry learning was more effective in improving students' academic performance and attitudes toward Biology. The study therefore recommended that Biology teachers should adopt AI-assisted inquiry learning in the teaching of abstract Biology concepts and that educational stakeholders should provide the necessary digital infrastructure and professional development required for its effective classroom implementation.

Keywords:

AI-assisted inquiry, Concept Mapping, Biology, Academic Performance, Attitude,

1.0 Introduction

Biology education serves as a cornerstone for scientific literacy, providing students with the foundational knowledge necessary for understanding life processes, healthcare, agriculture, and technological advancement. In secondary schools, Biology is not merely a subject of academic requirement but a critical discipline for achieving sustainable development goals and fostering informed citizenship. Biology education is pivotal for developing scientific process skills, problem-solving abilities, and critical thinking among secondary school students. It is offered by many students in the secondary schools and it is a building bridge to chemistry, physics, Mathematics and Information science and other disciplines (Edikpo, et al., 2024). Beyond equipping learners with scientific knowledge, effective Biology instruction is expected to translate into measurable learning outcomes that reflect students' understanding, application, and retention of biological concepts. Consequently, the extent to which students achieve the intended learning outcomes has become an important indicator of the effectiveness of Biology instruction and the quality of teaching strategies employed in the classroom (Ukpong et al., 2026).

Academic performance in Biology is often measured through standardized achievement tests that assess students' understanding of core concepts such as cell biology, genetics, and ecology (Sharma & Sharma, 2025; Mwambua et al., 2025). However, despite its importance, students' academic performance and attitudes toward Biology remain suboptimal in many educational contexts. Persistent challenges include the abstract nature of biological concepts, such as cellular respiration and photosynthesis, which often overwhelm students when taught through traditional, teacher-centered methods (Oboho, et al., 2026; Elijah et al., 2026). However, performance levels remain inconsistent, with many students struggling to grasp abstract concepts due to the complexity of the subject matter and inadequate instructional resources (Harvey, 2024; Agada et al., 2025). Research by Akpan et al, 2022 has further shown that students' academic achievement is influenced by integration of digital technology in teaching and learning. For instance, school disciplinary climate and students' academic engagement have been identified as significant predictors of academic achievement in secondary schools (Uboh et al., 2026), while parental attitudes and institutional disciplinary authority also play important roles in shaping students' behaviour and academic success (Uboh et al., 2026). Similarly, teacher-related variables significantly influence students' achievement across science-related disciplines (Ekpo et al., 2026).

Attitude is a motivating feeling that significantly influences learning outcomes. Negative attitudes toward biology are frequently attributed to teacher-centered approaches that lack interactive elements (Bizimana & Sibomana, 2024; Francis et al., 2023). Conversely, positive attitudes are associated with instructional strategies that promote active participation and relevance to real-life situations. The importance of instructional resources in shaping students' attitudes has also been documented. Edet et al. (2025) reported that the availability and utilization of instructional materials significantly improved students' attitudes and performance, suggesting that engaging instructional approaches can positively influence learners' disposition toward science subjects.

The limitations of conventional teaching methods have necessitated the exploration of innovative instructional strategies that align with constructivist principles. The predominant use of lecture-based instruction limits active student engagement, resulting in rote memorization rather than meaningful conceptual understanding (Bizimana & Sibomana, 2024; Lawal et al., 2025). The limitations of conventional teaching methods have necessitated the exploration of innovative instructional strategies that align with constructivist principles. Among these are inquiry-based learning and other learner-centred approaches that promote active participation and conceptual understanding. Similar findings have been reported in science education, where innovative learner-centred strategies such as crossword puzzles, flashcards, gamification, collaborative learning, and model-based instruction significantly improved students' academic achievement and engagement (Umanah & Sunday, 2022; Ntegwung et al., 2026; Umanah & Sunday, 2025).

Among these, inquiry-based learning has emerged as a powerful approach that encourages students to ask questions, explore ideas, and discover answers independently, thereby enhancing both curiosity and confidence (Palaguyan & Abusama, 2025). Inquiry-based instruction has consistently been linked to improved student engagement and conceptual knowledge. Palaguyan and Abusama (2025) found that inquiry-based methods significantly enhanced Grade 8 students' understanding of biology concepts. Additionally, Manishimwe et al. (2022b) reported that inquiry-based learning positively affected students' attitudes toward biology in Rwanda.

Concurrently, the rapid evolution of Artificial Intelligence (AI) technologies has introduced new possibilities for science education. AI in education encompasses a range of technologies, including personalized learning systems, virtual laboratories, and intelligent tutoring systems. AI-supported instructional tools facilitate the visualization of abstract concepts through computer-based molecular modelling, computer-based visualization, and other interactive digital applications, while providing adaptive learning experiences tailored to students' individual learning needs (Sunday, et al 2025; Sunday, et al 2026). AI-assisted inquiry learning integrates these technologies into the inquiry process, allowing students to simulate experiments, analyze data, and receive instant feedback, thereby enhancing their scientific investigation skills (Telaumbanua, 2025; Sinyo & Sabtu, 2025; Itighise et al, 2023). Recent studies demonstrate that AI-driven personalized learning platforms significantly enhance students' comprehension and performance in Biology (Yususf et al., 2025; Najmuddeen et al., 2024). For instance, Yususf et al. (2025) found that AI-powered virtual laboratories improved students' ability to conduct biological experiments and understand complex concepts. Similarly, Sinyo and Sabtu (2025) reported that AI-based media significantly improved critical thinking skills in biology learning. The integration of AI has also been shown to positively influence students' attitudes toward science. Sunday et al. (2025a) found that AI-powered tools enhanced undergraduate students' entrepreneurial skills, while Sunday et al. (2025b) reported that AI-powered learning tools significantly contributed to the development of critical thinking skills among learners. In secondary school science education, Atabang et al. (2026) revealed that AI-generated content improved students' mastery of physics concepts, highlighting the transformative role of AI in facilitating meaningful learning experiences. These findings suggest that AI-assisted inquiry learning may provide an effective pathway for improving students' academic performance and attitudes in Biology.

Parallel to technological advancements, concept mapping remains a robust visual learning strategy that allows students to organize and structure information meaningfully. Concept mapping is a visual representation of knowledge that helps learners identify relationships between concepts. It serves as both a learning tool and an assessment method, promoting meaningful learning by linking new information to existing cognitive structures (Sharma & Sharma, 2025; Azure et al., 2024). Recent research highlights the potential of concept mapping as a retrieval-based task, where students construct maps from memory to reinforce learning (Azure et al., 2024). Numerous studies confirm the effectiveness of concept mapping in improving academic achievement. Sharma and Sharma (2025) demonstrated that concept mapping significantly improved IX standard students' achievement in cell biology. Similarly, Mwambua et al. (2025) found that the Concept Mapping Teaching Approach enhanced Biology achievement among secondary school students in Kenya. Bizimana and Sibomana (2024) also reported positive effects of concept mapping on students' attitudes, particularly in rural settings. Recent studies further indicate that concept mapping is particularly effective in improving students' attitudes toward Biology, especially in rural settings where traditional methods often fail to engage learners (Bizimana & Sibomana, 2024).

Theoretical frameworks provide support for the use of AI-assisted inquiry and concept mapping strategies. Constructivist Learning Theory, proposed by Piaget and Vygotsky, posits that learners actively construct knowledge through experiences and social interactions (Zha et al., 2025). Both AI-assisted inquiry and concept mapping align with this theory by encouraging students to explore, question, and organize information actively. Inquiry-Based Learning Theory emphasizes the importance of questioning and investigation in the learning process. AI-assisted inquiry extends this by providing digital tools that support hypothesis testing and data analysis, making the inquiry process more accessible and engaging (Palaguyan & Abusama, 2025; Omovie & Kpangban, 2023). Ausubel's Meaningful Learning Theory suggests that learning occurs when new information is related to relevant concepts already possessed by the learner (Azure et al., 2024). Concept mapping directly supports this by requiring students to explicitly define relationships between concepts, thereby facilitating meaningful integration of knowledge. Siemens' Connectivism Theory highlights the role of technology in connecting learners to diverse information sources. AI-assisted learning embodies this principle by leveraging digital networks to provide personalized and interconnected learning experiences (Telaumbanua, 2025; Ramli & Mahmud, 2025).

While individual studies highlight the benefits of AI and concept mapping, comparative research remains limited. Bizimana et al. (2022b) compared concept mapping with cooperative mastery learning, finding both strategies effective in enhancing attitudes. However, there is a scarcity of studies directly comparing AI-assisted inquiry with concept mapping, underscoring the need for the present investigation. Despite the growing body of literature on individual instructional strategies, there is a notable research gap regarding the comparative effectiveness of AI-

assisted inquiry and concept mapping within the same experimental framework. While previous studies have examined the impact of concept mapping on academic achievement (Mwambua et al., 2025; Bizimana et al., 2022a) and the role of AI-assisted inquiry learning in enhancing students' engagement and conceptual understanding (Najmuddeen et al., 2024), none has directly compared these two innovative instructional approaches in terms of their effects on students' academic performance and attitudes toward Biology. Consequently, there is limited empirical evidence to guide educators on the relative effectiveness of AI-assisted inquiry learning and concept mapping in Biology classrooms. This study was therefore undertaken to compare the effects of AI-assisted inquiry learning and concept mapping on secondary school students' academic performance and attitudes toward Biology. The findings are expected to provide empirical evidence that will assist curriculum planners, teachers, and other education stakeholders in selecting effective learner-centred instructional strategies for improving Biology teaching and learning in the digital age

2.0 Statement of the Problem

Biology education is pivotal for developing scientific process skills, problem-solving abilities, and critical thinking among secondary school students. It is offered by many students in the secondary schools and it is a building bridge to chemistry, physics, Mathematics and Information science and other discipline. Despite its importance, students' academic performance in Biology at the secondary school level has continued to raise concerns, with many learners demonstrating inadequate understanding of fundamental biological concepts and developing unfavourable attitudes toward the subject. The persistent poor learning outcomes have been attributed to the abstract nature of several Biology concepts and the continued reliance on conventional teacher-centred instructional approaches that encourage rote memorization rather than conceptual understanding. Although factors such as school climate, learner characteristics, parental support, and teacher quality have been identified as contributors to students' achievement, the instructional approach adopted in the classroom remains one of the most influential determinants of meaningful learning and positive attitudes.

To address these challenges, learner-centred instructional strategies such as inquiry-based learning and concept mapping have received considerable attention because of their potential to actively engage students in the learning process. More recently, advances in artificial intelligence have introduced innovative instructional opportunities through AI-assisted inquiry learning, enabling students to visualize complex concepts, conduct virtual investigations, receive immediate feedback, and participate in personalized learning experiences. Similarly, concept mapping has continued to demonstrate effectiveness in helping learners organize knowledge, establish conceptual relationships, and improve retention of biological concepts. While previous studies have independently reported positive effects of AI-supported learning and concept mapping on students' academic achievement, engagement, and attitudes, empirical evidence directly comparing the effectiveness of AI-assisted inquiry learning and concept mapping within the same instructional context remains limited, particularly among secondary school Biology students. Consequently, it is not yet clear which of these innovative instructional approaches provides greater benefits over the conventional teaching method in improving students' academic performance and attitudes toward Biology. This unresolved gap necessitated the present study, which investigated the comparative effects of AI-assisted inquiry learning and concept mapping on secondary school students' academic performance and attitudes toward Biology.

Research Questions

1. What are the mean performance scores of students teaching the concept of cellular respiration using AI-assisted inquiry and concept mapping learning strategies?
2. What are the mean attitude scores of students teaching the concept of cellular respiration using AI-assisted inquiry and concept mapping learning strategies?

Hypotheses

1. There is no significant difference in the mean performance scores of students taught the concept of cellular respiration using AI-assisted inquiry and concept mapping learning strategies?
2. There is no significant difference in the mean attitude scores of students taught the concept of cellular respiration using AI-assisted inquiry and concept mapping learning strategies?

2.1 Research Methods

This study adopted a quasi-experimental pretest-posttest non-equivalent comparison group design**.** The study was conducted in Eket Local Government Area of Akwa Ibom State, Nigeria. The population comprised all Senior Secondary Two (SS II) Biology students in public secondary schools in the study area. Two public secondary schools were selected using simple random sampling. Thereafter, one intact SS II Biology class was selected from each school. The intact classes constituted the sample for the study, giving a total of 87 students. One school, comprising 46 students, served as the AI-Assisted Inquiry Learning Group, while the other school, comprising 41 students, served as the Concept Mapping Learning Group. AI-Assisted Inquiry Learning Group: Students in the AI-Assisted Inquiry Learning Group were taught the concept of *Cellular Respiration* through teacher-guided AI-assisted inquiry lessons using ChatGPT and LabXchange as instructional support tools. At the beginning of each lesson, the teacher introduced the concept and demonstrated how the AI platforms would be used to facilitate learning. Due to the limited availability of digital devices, ChatGPT and LabXchange were projected for whole-class instruction while students participated in guided inquiry activities. The teacher used ChatGPT to explain difficult concepts, respond to students' questions, provide immediate feedback, and reinforce classroom discussions, whereas LabXchange was used to demonstrate virtual laboratory simulations of cellular respiration, enabling students to visualize mitochondrial processes, ATP production, and energy transformation. Throughout the lessons, the teacher facilitated discussions, guided students in interpreting observations, corrected misconceptions, and encouraged active participation to promote conceptual understanding and positive attitudes toward Biology.

Students in the Concept Mapping Learning Group were taught through teacher-guided concept mapping lessons. The teacher introduced each Biology concept, demonstrated the construction of concept maps, and guided students in identifying and linking related biological concepts using hierarchical diagrams. Students then developed concept maps individually and in groups under the teacher's supervision, after which feedback and corrections were provided to reinforce meaningful learning. Two instruments were used for data collection: the *Cellular Respiration* Performance Test (CRPT) and the Biology Attitude Scale (BAS). The CRPT was a 20 item multiple-choice questions while BAS utilized a four-point Likert-Scale rating with response options: "Strongly Agree" (SA), "Agree" (A), "Disagree" (D), and "Strongly Disagree" (SD), with corresponding numerical values of 4, 3, 2, and 1, respectively for respondents to provide their ratings. The reliability of the instruments was determined using Kuder-Richardson K-20 for AICRLP and Cronbach Alpha for BAS with reliability coefficients established at 0.78 and 0.82 respectively. Data collected were analyzed using mean and standard deviation to answer the research questions, while Analysis of Covariance (ANCOVA) was used to test the hypotheses at the 0.05 level of significance.

Results

Research Question One: What are the mean performance scores of students teaching the concept of cellular respiration using AI-assisted inquiry and concept mapping learning strategies?

Table 1: Mean and standard deviation of pretest and posttest performance scores of students taught cellular respiration using AI-assisted inquiry and concept mapping learning strategies

Learning Strategy	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Mean Gain
AI-Assisted Inquiry Learning	41	9.66	2.86	16.51	2.00	6.85
Concept Mapping	46	9.26	2.56	14.30	2.37	5.04

The result presented in Table 1 revealed that students taught cellular respiration using AI-assisted inquiry learning had a pretest mean score of **9.66** with a standard deviation of **2.86**, while their posttest mean score increased to **16.51** with a standard deviation of **2.00**, resulting in a mean gain of **6.85**. Students taught using the concept mapping learning strategy recorded a pretest mean score of **9.26** with a standard deviation of **2.56** and a posttest mean score of **14.30** with a standard deviation of **2.37**, yielding a mean gain of **5.04**. The result indicates that students exposed to both AI-assisted inquiry and concept mapping learning strategies improved in their academic performance after the treatment. However, students taught using AI-assisted inquiry learning obtained a higher posttest mean score and greater mean gain than those taught using the concept mapping learning strategy. This suggests that AI-assisted inquiry learning was more effective in improving students' academic performance in the concept of cellular respiration.

Research Question Two: What are the mean attitude scores of students teaching the concept of cellular respiration using AI-assisted inquiry and concept mapping learning strategies?

Table 2: Mean and standard deviation of pre-attitude and post-attitude scores of students taught cellular respiration using AI-assisted inquiry and concept mapping learning strategies

Learning Strategy	N	Pre-Attitude Mean	Pre-Attitude SD	Post-Attitude Mean	Post-Attitude SD	Mean Gain
AI-Assisted Inquiry Learning	41	2.17	0.57	3.62	0.29	1.44
Concept Mapping	46	2.27	0.50	3.40	0.28	1.13

The result presented in Table 4.2 showed that students taught cellular respiration using AI-assisted inquiry learning had a pre-attitude mean score of **2.17** with a standard deviation of **0.57**, while their post-attitude mean score increased to **3.62** with a standard deviation of **0.29**, giving a mean gain of **1.44**. Students taught using the concept mapping learning strategy obtained a pre-attitude mean score of **2.27** with a standard deviation of **0.50** and a post-attitude mean score of **3.40** with a standard deviation of **0.28**, resulting in a mean gain of **1.13**. The result indicates that both instructional strategies enhanced students' attitudes toward Biology after the treatment. However, students exposed to AI-assisted inquiry learning recorded a higher post-attitude mean score and greater mean gain than those taught using the concept mapping learning strategy. This implies that AI-assisted inquiry learning was more effective in improving students' attitudes toward Biology than the concept mapping learning strategy.

Hypothesis One: There is no significant difference in the mean performance scores of students taught the concept of cellular respiration using AI-assisted inquiry and concept mapping learning strategies.

Table 3: Analysis of Covariance (ANCOVA) of the difference in the mean performance scores of students taught cellular respiration using AI-assisted inquiry and concept mapping learning strategies using pretest scores as covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	109.769	2	54.884	11.303	.000
Intercept	1684.002	1	1684.002	346.803	.000
Pretest	4.096	1	4.096	0.844	.361
Learning Strategies	**108.188**	**1**	**108.188**	**22.280**	**.000**
Error	407.887	84	4.856		
Total	21003.000	87			
Corrected Total	517.655	86			

R^2 = .212 (Adjusted R^2 = .193).

The result presented in Table 3 showed that the effect of learning strategies on students' academic performance in cellular respiration was statistically significant after controlling for the influence of pretest scores (**F** (1,84) = **22.280**, **p** = **.000**). The probability value of **.000** is less than the 0.05 level of significance. Therefore, the null hypothesis was **rejected**. This implies that there was a significant difference in the mean performance scores of students taught cellular respiration using AI-assisted inquiry and concept mapping learning strategies. Based on the descriptive statistics presented in Table 1, students taught using AI-assisted inquiry learning performed significantly better than those taught using the concept mapping learning strategy.

Hypothesis Two: There is no significant difference in the mean attitude scores of students taught the concept of cellular respiration using AI-assisted inquiry and concept mapping learning strategies.

Table 4: Analysis of Covariance (ANCOVA) of the difference in the mean attitude scores of students taught cellular respiration using AI-assisted inquiry learning and concept mapping learning strategies using pre-attitude scores as covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.123	2	0.561	7.035	.001
Intercept	53.110	1	53.110	665.716	.000
Pre-Attitude	0.072	1	0.072	0.897	.346
Learning Strategies	**1.091**	**1**	**1.091**	**13.680**	**.000**
Error	6.701	84	0.080		
Total	1073.527	87			
Corrected Total	7.824	86			

R^2 = .143 (Adjusted R^2 = .123).

The result presented in Table 4 revealed that the effect of learning strategy on students' attitude toward Biology was statistically significant after controlling for the influence of pre-attitude scores (**F** (1,84) = **13.680**, **p** = **.000**). Since the probability value of **.000** is less than the 0.05 level of significance, the null hypothesis was **rejected**. The finding indicates that there was a significant difference in the mean attitude scores of students taught cellular respiration using AI-assisted inquiry learning and concept mapping learning strategies. The descriptive statistics in Table 2 further showed that students exposed to AI-assisted inquiry learning developed significantly more positive attitudes toward Biology than those taught using the concept mapping learning strategy.

3.0 Discussion of Findings

The finding of this study revealed that there was a significant difference in the academic performance of students taught cellular respiration using AI-assisted inquiry and concept mapping learning strategies, with students exposed to AI-assisted inquiry learning demonstrating better academic performance than those taught using concept mapping. The superior performance associated with AI-assisted inquiry learning may be attributed to its ability to actively engage learners in the learning process through investigation, exploration, experimentation, and immediate feedback. By integrating artificial intelligence into inquiry activities, students were provided with opportunities to visualize abstract biological processes, interact with digital learning environments, and receive personalized support, thereby promoting deeper conceptual understanding of cellular respiration. This finding supports the assertion that learner-centred instructional strategies enhance meaningful learning and improve students' understanding of Biology concepts beyond what is achieved through conventional instructional approaches.

The finding is consistent with the report of Palaguyan and Abusama (2025), who found that inquiry-based learning significantly enhanced students' understanding of Biology concepts. It also agrees with the findings of Yusuf et al. (2025) and Najmuddeen et al. (2024), who reported that AI-driven learning environments improved students' comprehension and academic performance in Biology through personalized learning experiences. Likewise, the finding corroborates the studies of Sunday, Umanah, and Udofia (2025) and Sunday, Umanah, Ntegwung, and Akpan (2026), who demonstrated that computer-based molecular modelling and computer-based visualization enhanced students' understanding of abstract science concepts. Although concept mapping also improved students' performance, the present finding suggests that combining artificial intelligence with inquiry learning provides a richer and more interactive learning experience capable of producing greater improvements in students' academic achievement.

The finding of this study also showed that there was a significant difference in the attitudes of students taught cellular respiration using AI-assisted inquiry learning and concept mapping learning strategies, with students exposed to AI-assisted inquiry learning developing more positive attitudes toward Biology than those taught using concept mapping. This outcome may be attributed to the interactive and engaging nature of AI-assisted inquiry learning, which encourages students to participate actively in scientific investigations, ask questions, explore biological phenomena, and receive immediate feedback throughout the learning process. Such learning experiences are capable of increasing learners' confidence, curiosity, motivation, and interest in Biology, thereby fostering more positive attitudes toward the subject.

The finding agrees with Manishimwe et al. (2022b), who reported that inquiry-based learning positively influenced students' attitudes toward Biology. It also supports the findings of Sunday et al. (2025a) and Sunday et al. (2025b), who found that AI-supported learning environments enhanced important learner outcomes by promoting active engagement and higher-order thinking. Similarly, the finding is in line with Bizimana and Sibomana (2024), who reported that concept mapping improved students' attitudes toward Biology by facilitating meaningful learning. However, the present study demonstrates that integrating artificial intelligence with inquiry-based learning offers

greater opportunities for interaction, personalization, and active participation than concept mapping alone, resulting in more favourable attitudes toward Biology. This finding further supports the view that innovative learner-centred instructional approaches are more effective in promoting positive learning dispositions than traditional teaching methods.

4.0 Conclusion

The study concluded that both AI-assisted inquiry and concept mapping are effective learner-centred instructional strategies for improving students' academic performance and attitudes toward Biology. However, AI-assisted inquiry learning proved to be more effective than concept mapping in enhancing students' understanding of cellular respiration and fostering more positive attitudes toward the subject. The integration of artificial intelligence into inquiry-based learning provided students with interactive, personalized, and engaging learning experiences that promoted meaningful conceptual understanding and active participation. Therefore, AI-assisted inquiry learning represents a more effective instructional approach for teaching abstract Biology concepts in secondary schools and should be encouraged as part of efforts to improve Biology teaching and learning in the digital age.

5.0 Recommendations

Based on the findings of this study, the following recommendations were made:

1. Biology teachers should adopt AI-assisted inquiry learning in the teaching of abstract Biology concepts such as cellular respiration to improve students' academic performance and attitudes toward the subject.
2. Curriculum planners should incorporate AI-assisted inquiry learning activities and digital instructional resources into the secondary school Biology curriculum to promote learner-centred and technology-enhanced instruction.
3. School administrators and education stakeholders should provide adequate AI-enabled instructional facilities, including computers, internet connectivity, interactive software, and virtual laboratory applications, to facilitate effective implementation of AI-assisted inquiry learning.
4. Government and educational agencies should organize regular workshops, seminars, and in-service training programmes to equip Biology teachers with the knowledge and skills required for integrating artificial intelligence into inquiry-based classroom instruction.

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