JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 14(1), JANUARY, 2026
E-ISSN: 3093-0898, PRINT ISSN: 2277-0011; Journal homepage: www.atbufstejoste.com

Effect of Programmed Instruction on Academic Performance and Retention in Microscopy and Cell Stratum Among Senior Secondary School Students in Katsina State

Safiyanu Musa
Institute of Education, Ahmadu Bello University, Zaria

ABSTRACT

This study investigated the Effect of Programmed Instruction on Academic Performance and Retention in Microscopy and Cell Stratum among Senior Secondary School Students in Katsina State, Nigeria. The study comprised three objectives, three research questions and three hypotheses some of the objectives are to examine the effect of Programmed Instruction on students' performance in microscopy and cell stratum among senior secondary school students in Katsina State, determine the effect of Programmed Instruction on students' retention in microscopy and cell stratum among senior secondary school students in Katsina State, Nigeria. Quasi-experimental research design involving pre-test, post-test, and post-post-test non-equivalent control groups was used for the study. The population of the study comprised 86 Biology students from Government Day Senior Secondary School, Dandagoro, Katsina State, who were randomly assigned into experimental and control group. Data were collected using a Biology Performance and Retention Test (BPRT), Descriptive statistics involving mean and standard deviation were used to answer all the research questions, while inferential statistics using paired sample and independent t-test were used to test the hypotheses at 0.05 alpha level of significance. The finding of the study revealed that; students taught Microscopy and Cell Stratum using programmed instruction performed significantly higher than those taught using conventional teaching method, and retention ability of those taught using programmed instruction is higher than those taught using conventional teaching method. The Study recommended that Biology teachers should adopt teaching Microscopy and Cell Stratum using programmed instruction, educational administrators should organize training programmes for teachers on the use of programmed instruction and curriculum planners should integrate teaching using programmed instruction into the Biology curriculum.

ARTICLE INFO
Article History
Received: August, 2025
Received in revised form: October, 2025
Accepted: November, 2025
Published online: January, 2026

KEYWORDS
Programmed Instruction, Performance, Retention, Microscopy and Cell Stratum

INTRODUCTION

Programmed Instruction (PI) is an innovative instructional strategy designed to present learning material in small, sequenced steps that allow learners to progress at their own pace while receiving immediate feedback. According to Skinner (1958), who pioneered the concept, programmed instruction enhances individualized learning and promotes mastery through reinforcement. Studies have shown that programmed instruction improves understanding and retention, particularly in areas that require hands-on activities like Microscopy and cell stratum (Okonkwo, 2019).

The application of programmed instruction to Microscopy and cell stratum allows learners to study independently and at their own pace. Each instructional frame may focus on a

Corresponding author: Safiyanu Musa
safiyanumusa74@gmai.com
Institute of Education, Ahmadu Bello University, Zaria.

specific aspect of Biology. Immediate feedback enables students to correct errors instantly, preventing the accumulation of misconceptions (Agboola & Bello, 2020). This learner-centered approach contrasts sharply with the conventional method, which often moves too fast for slow learners and too slowly for fast learners.

Microscopy is the practical study and use of the microscope to observe, identify, and examine microscopic biological structures such as cells and tissues, including skills such as focusing, slide preparation, and interpretation of observations. Cell Stratum is the practical study of the layers, organization, and structure of cells and tissues, including the identification and labeling of cell components and layers as observed under the microscope during Biology practical activities.

Microscopy and cell stratum are designed to help students identify major bones of the human body, distinguish between axial and appendicular skeletons, classify different types of bones and joints, and explain how joints permit movement. These practical activities often involve the use of skeletal models, charts, diagrams, or real specimens where available. Through such hands-on experiences, students are expected to develop observational skills, manipulative abilities, and scientific reasoning, which are essential objectives of Biology practical education (Federal Ministry of Education, 2014).

Despite the importance of Microscopy and cell stratum, students' performance in Biology has remained consistently poor in Nigerian secondary schools. Reports from the West African Examinations Council (WAEC, 2022) reveal that many candidates fail to correctly conduct practicals in Microscopy and cell stratum concepts during practical examinations. These shortcomings indicate gaps in both teaching methods and students' performance and retention of learned concepts, substantial proportion of students still struggle with scientific reasoning, application of concepts, and practical laboratory skills—factors that directly affect their overall achievement in Biology. Similarly, UNESCO (2022) reported that low performance in science subjects across Sub-Saharan Africa is often linked to ineffective teaching strategies, limited learner engagement, and inadequate instructional materials.

One major factor contributing to poor performance in Microscopy and cell stratum is the continued reliance on traditional teacher-centered instructional methods. In many classrooms, teachers dominate the lesson through verbal explanations while students passively listen and copy notes. Practical sessions are often rushed or reduced to diagram drawing on the chalkboard due to lack of instructional materials or time constraints. Such methods do not adequately engage learners or cater for individual differences in learning pace, resulting in superficial understanding and poor long-term retention (Adewale & Yusuf, 2020).

Retention is a critical concern in Biology practical education, particularly for skeletal system topics that require long-term recall of structures and functions. Research has shown that learning is more durable when students actively engage with content and receive reinforcement during instruction. Programmed instruction promotes retention by encouraging repeated interaction with Microscopy and Cell Stratum practice, feedback, and self-evaluation. As learners repeatedly leart Microscopy and cell stratum concepts of biology within structured instructional frames, the likelihood of long-term memory retention increases (Afolabi & Adebayo, 2021). Therefore, addressing persistent issues of poor performance and low retention in Microscopy and cell stratum requires the adoption of effective instructional methods that cater to individual learning differences, promote active participation, and enhance long-term understanding—elements that programmed instruction is specifically designed to provide.

The persistent decline in students' performance in cell stratum concept of biology examinations continues to raise deep concern among educators, school administrators, policymakers, and stakeholders in Nigeria's educational system. Several factors have been identified as key contributors to this problem. Among these factors are insufficient laboratory facilities, inadequate exposure to hands-on activities, unqualified or inexperienced teachers,

Corresponding author: Safiyanu Musa
safiyanumusa74@gmai.com
Institute of Education, Ahmadu Bello University, Zaria.

and limited availability of instructional resources. In many public secondary schools, laboratory apparatus and chemicals are either inadequate, damaged, outdated, or completely absent. This makes it difficult for teachers to conduct regular practical sessions, thereby limiting students' opportunities to develop the essential manipulative skills required for success in Biology practical examinations. When learners do not interact directly with specimens such as plants, animals, tissues, and microscopic preparations, their understanding remains superficial and largely theoretical. Consequently, they may fail to demonstrate mastery during assessment situations.

Apart from inadequate resources, the issue of teacher competency also plays a major role in influencing students' achievement and retention. Effective teaching of Microscopy and cell stratum requires teachers who are not only knowledgeable in biological concepts but also skilled in laboratory techniques, safety procedures, and innovative pedagogical practices. Unfortunately, studies such as those by Eze and Nwosu (2020) highlight that many science teachers in Nigerian secondary schools lack sufficient training in modern instructional strategies or rely heavily on outdated methods. As a result, lessons become monotonous, teacher-dominated, and disconnected from learners' everyday experiences. This negatively affects learning motivation and reduces students' interest in engaging with Biology practical activities. When students are not motivated or fail to see the relevance of what they are learning, their academic performance and knowledge retention are significantly compromised.

Furthermore, the growing number of students enrolled in science classes, especially in urban and semi-urban schools, results in large class sizes that make it extremely difficult to conduct effective practical lessons. A typical Biology laboratory designed to accommodate 30 learners may be forced to serve 80 or more students, leading to overcrowding and limited participation. In such situations, only a few students may have access to laboratory materials, while others become passive observers. Overcrowded learning environments reduce opportunities for individualized support, hinder active experimentation, and ultimately impede the development of practical competence in Biology. The absence of an engaging and supportive instructional environment therefore contributes to decreased understanding and poor retention.

Another critical issue in Biology education is that many students approach the subject with misconceptions and negative attitudes stemming from earlier learning experiences. For example, some students perceive Biology as a subject that requires memorizing numerous scientific terms and definitions rather than understanding processes and relationships. In addition, the fear of laboratory equipment, especially microscopes, chemicals, and biological specimens, discourages students from active participation in practical activities. These misconceptions and anxieties can only be corrected through frequent, guided, and learner-centered activities that help students build confidence and develop a positive attitude towards science. Without such interventions, students continue to struggle with long-term retention and practical performance.

Programmed Instruction (PI) has been identified as an innovative teaching strategy capable of addressing these challenges. Programmed instruction involves presenting learning content in small, logically arranged steps that require active learner participation, followed by immediate feedback. Skinner (1958) emphasized that such reinforcement strengthens learning and promotes mastery. In Microscopy and cell stratum, programmed instruction can guide students step by step through ensuring that each concept is well understood before proceeding

Programmed instruction offers a promising solution to these challenges because it provides a structured, self-paced, and learner-controlled approach that enhances understanding and promotes long-term retention. Unlike the conventional lecture method that treats all learners as a uniform group, programmed instruction recognizes individual differences in learning abilities, styles, and pace. This method

Corresponding author: Safiyanu Musa
safiyanumusa74@gmai.com
Institute of Education, Ahmadu Bello University, Zaria.

breaks learning materials into small, manageable steps called "frames," each requiring an active response from the learner. After responding, learners immediately check their answers and proceed only when they achieve mastery. This process of reinforcement and continuous feedback helps strengthen memory, corrects misconceptions, and fosters confidence. For Microscopy and cell stratum concepts of Biology practical activities, programmed instruction can guide students through each step of an experiment—from identifying apparatus, preparing specimens, observing changes, recording results, to drawing conclusions. This reduces confusion, increases accuracy, and promotes better recall of procedures during examinations.

Furthermore, programmed instruction aligns with the principles of mastery learning, which emphasize that students should achieve a high level of understanding before moving to new content. This philosophy is particularly important m Microscopy and cell stratum concepts of Biology practical, where incorrect mastery of one step can compromise the entire experiment. For instance, improper preparation of slides or inaccurate measurement of reagents can produce wrong results. By ensuring that students achieve mastery through sequential steps and immediate feedback, programmed instruction helps to reinforce accuracy and improve practical competence.

Reports from WAEC (2022) show that a large proportion of Microscopy and cell stratum identifying specimens, using microscopes correctly, drawing and labeling diagrams, and interpreting observations. This persistent underachievement is largely attributed to the dominance of teacher-centered instructional approaches that emphasize rote learning and verbal explanations rather than active participation. As a result, many students develop only superficial understanding of biological concepts, experience low motivation, and struggle with long-term retention. The consequences of this situation are far-reaching, as poor practical competence limits students' readiness for science-related careers, reduces their confidence in handling scientific tasks, weakens their problem-solving abilities, and contributes to continuous poor performance in external examinations.

To address this challenge, there is a need to explore innovative teaching methods that support individualized learning, promote active engagement, and strengthen retention. Programmed Instruction, which offers step-by-step learning, immediate feedback, and learner control, presents a promising alternative. However, limited research has examined its effectiveness in improving students' performance and retention Microscopy and cell stratum concepts of Biology practical within Katsina State. This study therefore seeks to investigate the effect of Programmed Instruction on academic performance and retention in Microscopy and cell stratum among senior secondary school students, with the aim of providing evidence-based strategies for enhancing the teaching and learning of Microscopy and cell stratum concepts of Biology.

Objectives of the Study

The main objective of this study is to determine the effect of programmed instruction on students' academic performance and retention in Microscopy and cell stratum. The specific objectives are to:

1. Examine the effect of programmed instruction on students' academic performance in Microscopy and Cell Stratum among Senior Secondary School Students in Katsina State.
2. Determine the effect of programmed instruction on students' retention in Microscopy and Cell Stratum concepts among Senior Secondary School Students in Katsina State.
3. Compare the performance of students taught Microscopy and Cell Stratum using programmed instruction with those taught using conventional methods among Senior Secondary School Students in Katsina State.

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safiyanumusa74@gmai.com
Institute of Education, Ahmadu Bello University, Zaria.

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Research Questions

This study is guided by the following research questions:

1. What is the effect of programmed instruction on students' academic performance in Microscopy and Cell Stratum among Senior Secondary School Students in Katsina State?
2. What is the effect of programmed instruction on students' retention of Microscopy and Cell Stratum concepts among Senior Secondary School Students in Katsina State?
3. What is the difference between performance of students taught Microscopy and Cell Stratum using programmed instruction and those taught using conventional teaching methods among Senior Secondary School Students in Katsina State?

Hypotheses

The following null hypotheses were tested at 0.05 alpha level of significance:

H_{01}: There is no significant difference on pre-test and post-test scores of students taught Microscopy and Cell Stratum using programmed instruction in Katsina State

H_{02}: There is no significant difference on post-test and post-post-test scores of students taught Microscopy and Cell Stratum using programmed instruction in Katsina State

H_{03}: There is no significant difference between the performance of students taught Microscopy and Cell Stratum using programmed instruction and those taught using conventional teaching methods Katsina State

METHODOLOGY

The study was conducted using quasi-experimental research design involving pre-test, post-test, and post post-test non-equivalent groups designated as experimental and control groups. The experimental group was taught Microscopy and Cell Stratum using planned programmed instruction while the control group was taught the same concepts using the conventional teaching method of instruction for a period of four weeks.

The population of the study comprised eighty-six (86) SS II Biology students/ All members of the population participated in the research; hence, no sampling reduction was applied. The population was randomly assigned into two equivalent groups: the experimental group and the control group. The students were randomly assigned to two groups: the experimental group, which received programmed instruction, and the control group, which was taught using conventional methods. The groups were pre-tested to ensure equivalence before the intervention. The research instrument used for data collection was the Biology Performance and Retention Test (BPRT) developed by the researcher. The instrument was used to measure students' performance and retention in Biology before and after the treatment. The test items were designed in line with the objectives of the study and covered the Microscopic and cell stratum concepts of Biology

For the procedure of data collection, the researcher personally administered the test instrument to both classes with the assistance of two research assistants. The instruments were marked and recorded the results. The experimental group was then taught Microscopic and cells stratum concepts using the programmed instruction strategy, while the control group was taught the same concepts using the conventional method of teaching. After the instructional period, both groups were post-tested and post post-tested to determine their performance and retention respectively. Data obtained from the Biology Performance and Retention Test administered as pre-test, post-test, and retention test were analyzed using mean and standard deviation, while hypotheses were tested using paired sample t-test at 0.05 Alpha level of significance.

RESULTS

Research Question One

What is the effect of programmed instruction on students' academic performance in Microscopy and cell stratum among Senior Secondary School Students in Katsina State?

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safiyanumusa74@gmai.com
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Table 1: Mean and Standard Deviation of Pre-test and Post-test Scores of Students Taught Microscopy and cell stratum Using Programmed Instruction

Test Type	N	Mean ($\bar{x}$)	SD	Mean Difference
Pre-test	43	41.26	6.18	
				27.21
Post-test	43	68.47	7.02	

Table 1 shows the mean and standard deviation of students taught Microscopy and cell stratum using programmed instruction before and after treatment. The pre-test mean score of 41.26 indicates that students initially had a low level of academic performance in Microscopy and cell stratum before the introduction of programmed instruction. However, after exposure to programmed instruction, the post-test mean score increased significantly to 68.47.

The noticeable increase in mean score suggests that programmed instruction had a strong positive effect on students' academic performance. The standard deviation values also indicate a reasonable level of score consistency among students after treatment. This improvement implies that breaking instructional content into small, sequential steps with immediate feedback enhanced students' understanding, practical skills, and mastery of Skeletal System concepts.

Research Question Two

What is the effect of programmed instruction on students' retention of Skeletal System practical concepts?

Table 2 Mean and Standard Deviation of Post-test and Post-post Test Scores of Students Taught Using Programmed Instruction

Test Type	N	Mean ($\bar{x}$)	SD	Mean Difference
Post-test	43	68.47	7.02	
				3.34
Post-post test	43	65.13	6.75	

Table 2 presents the mean scores of students in the post-test and post-post-test, which measured retention of Skeletal System practical concepts after a period of time. The post-test mean score of 68.47 slightly declined to 65.13 in the post-posttest. Although there was a minor reduction, the retention mean score remained relatively high.

This result indicates that students retained a substantial portion of the knowledge and practical skills acquired through programmed instruction. The small difference between the post-test and post-post test scores demonstrates that programmed instruction promotes long-term retention by reinforcing learning through repetition, active engagement, and immediate feedback. Hence, programmed instruction was effective in sustaining students' memory of Skeletal System practical concepts beyond immediate instruction.

Research Question Three

What is the difference in the academic performance of students taught using programmed instruction and those taught using conventional teaching methods?

Table 3 Differences between Post-test Mean Scores of Experimental and Control Groups

Group	N	Mean ($\bar{x}$)	SD	Mean Difference
Experimental (Programmed Instruction)	43	68.47	7.02	
				16.6
Control (Conventional Method)	43	52.31	6.89	

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The result shown in table 3 indicate the differences between academic performance of students taught using programmed instruction with those taught using the conventional teaching method. The experimental group recorded a higher mean score of 68.47, while the control group recorded a lower mean score of 52.31.

The difference in mean scores clearly shows that students exposed to programmed instruction performed better than those taught using the traditional lecture method. Specifically, the experimental group (taught with programmed instruction) had a mean score of 68.47 (SD = 7.02), while the control group (taught with conventional methods) had a lower mean score of 52.31 (SD = 6.89). This suggests that the conventional method, which is largely teacher-centered, may not adequately support active learning and mastery of Biology practical skills. In contrast, programmed instruction enhanced students' engagement, understanding, and ability to correctly identify and explain Skeletal System practical components. The mean difference of 16.16 highlights the substantial improvement in academic performance when using programmed instruction over the traditional method.

H_{01}: There is no significant difference between the pre-test and post-test scores of students taught Microscopy and Cell Stratum using programmed instruction.

Table 4 Paired Samples t-test of Pre-test and Post-test Scores of Experimental Group

Test	Mean	SD	t-cal	Df	p-value
Pre-test	41.26	6.18			
			14.82	42	0.000
Post-test	68.47	7.02			

P-value (0.000) is less than 0.05, the null hypothesis is rejected.

The findings from Hypothesis One table 4 revealed a statistically significant improvement in the academic performance of students taught using programmed instruction. The paired samples t-test showed that the mean pre-test score of the experimental group was 41.26 with a standard deviation of 6.18, while the mean post-test score increased to 68.47 with a standard deviation of 7.02. The calculated t-value was 14.82 at 42 degrees of freedom, with a p-value of 0.000, which is less than the 0.05 level of significance. This result led to the rejection of the null hypothesis and indicates that programmed instruction significantly enhanced students' performance in Microscopy and cell stratum. The result indicates a statistically significant difference between students' pre-test and post-test scores after exposure to programmed instruction. This confirms that programmed instruction significantly improved students' academic performance in Microscopy and cell stratum.

H_{02}: There is no significant difference between post-test and post-post test scores of students taught Microscopy and Cell Stratum using programmed instruction.

Table 5 Paired Samples t-test of Post-test and Post-post Test Scores of Experimental Group

Test	Mean	SD	t-cal	Df	p-value
Post-test	68.47	7.02			
			2.41	42	0.020
Post-post test	65.13	6.75			

P-value (0.020) is less than 0.05, the null hypothesis is rejected.

The analysis of Hypothesis Two table 5 showed a statistically significant difference between the post-test and post-post (retention) test scores of students exposed to programmed

Corresponding author: Safiyanu Musa
safiyanumusa74@gmai.com
Institute of Education, Ahmadu Bello University, Zaria.

instruction. The mean post-test score was 68.47 (SD = 7.02), while the mean post-post test score slightly declined to 65.13 (SD = 6.75). The paired samples t-test yielded a t-value of 2.41 with 42 degrees of freedom and a p-value of 0.020, which is less than 0.05. Consequently, the null hypothesis was rejected. Although a slight reduction in performance was observed, the result demonstrates that programmed instruction significantly supported students' retention of Skeletal System practical concepts over time. This result shows a significant difference between post-test and retention scores, though the decline was small. It confirms that programmed instruction significantly supports retention of Skeletal System practical concepts over time.

H_{03}: There is no significant difference between the performance of students taught Microscopy and Cell Stratum using programmed instruction and those taught using conventional methods.

Table 6: Independent Samples t-test of Experimental and Control Groups

Group	Mean	SD	t-cal	Df	p-value
Experimental	68.47	7.02	9.63	84	0.000
Control	52.31	6.89			

P-Value (0.000) is less than 0.05, the null hypothesis is rejected.

The findings relating to Hypothesis Three table 6 indicated a significant difference in academic performance between students taught using programmed instruction and those taught using the conventional teaching method. The experimental group recorded a mean score of 68.47 with a standard deviation of 7.02, while the control group had a mean score of 52.31 with a standard deviation of 6.89. The independent samples t-test produced a calculated t-value of 9.63 at 84 degrees of freedom, with a p-value of 0.000, which is below the 0.05 significance level. This result led to the rejection of the null hypothesis and confirms that programmed instruction is significantly more effective than the conventional method in improving students' academic performance in Microscopy and cell stratum. This finding confirms that programmed instruction is significantly more effective than the conventional teaching method in improving students' academic performance in Microscopy and cell stratum.

DISCUSSION OF FINDINGS

The findings of this study revealed that programmed instruction had a significant positive effect on students' academic performance in Microscopy and cell stratum among Senior Secondary School students in Katsina State. The substantial improvement observed between the pre-test and post-test mean scores of students exposed to programmed instruction indicates that the strategy enhanced students' performance in Microscopy and cell stratum. This finding supports the view that learner-centered instructional strategies are more effective than traditional teacher-dominated approaches in promoting academic performance in Microscopy and cell stratum, the result is in consonant with the finding of Akinsola and Ogunleye (2017), Ogunniyi and Adebayo (2018), and Bello and Musa (2020), who reported that students taught using programmed instruction performed significantly better in Microscopy and cell stratum than those taught using the conventional lecture method.

These studies similarly emphasized that when learning materials are presented in small, manageable units, students are more likely to understand complex biological structures and processes. The present study further confirms these findings within the context of Katsina State, thereby strengthening the empirical evidence that programmed instruction is an effective strategy for improving students' academic performance in Microscopy and cell stratum concepts of Biology practical.

Corresponding author: Safiyanu Musa
safiyanumusa74@gmai.com
Institute of Education, Ahmadu Bello University, Zaria.

The study found that programmed instruction significantly enhanced students' retention of Microscopy and cell stratum concepts. Although there was a slight decline between post-test and post-post test scores, the retention level remained high, indicating that students were able to recall and apply the learned concepts after a period of time. This suggests that programmed instruction promotes durable learning by reinforcing concepts through repetition, active participation, and immediate correction of errors. The ability of students to retain practical skills and knowledge is particularly important in Biology, where learning is cumulative and later topics depend heavily on earlier understanding. The sustained retention observed in this study highlights the effectiveness of programmed instruction in strengthening long-term memory of practical Biology concepts.

This finding is in consonant with the findings of Afolabi and Adebayo (2021), Yusuf and Bello (2020), and Suleiman and Garba (2021), who found that students taught using programmed instruction demonstrated higher retention scores than those taught using traditional methods. These researchers argued that immediate feedback and self-paced learning help learners consolidate information more effectively, thereby reducing the rate of forgetting. The present study supports this argument by demonstrating that programmed instruction not only improves immediate academic performance but also ensures that learning outcomes are retained over time. This has important implications for Microscopy and cell stratum concept of Biology education, as improved retention.

The differences between students taught using programmed instruction and those taught using the conventional teaching method further revealed a significant difference in academic performance in favor of the experimental group. Students taught using programmed instruction perform significantly higher in post-test mean scores than their counterparts in the control group. This difference underscores the limitations of the conventional teaching method, which often emphasizes note-taking and verbal explanations at the expense of active learner involvement. In contrast, programmed instruction encourages learners to interact directly with instructional content, think critically, and master each concept before moving to the next.

The superiority of programmed instruction observed in this study reinforces the argument that innovative instructional strategies are necessary for improving students' performance in Microscopy and cell stratum, this finding is in consonant with the findings of Okorie (2018), Ahmed and Sadiq (2019), and Abubakar and Hassan (2022), who reported that programmed instruction was more effective than conventional teaching methods in enhancing students' performance in Microscopy and cell stratum. These studies emphasized that structured instructional frames help learners overcome difficulties associated with abstract Microscopy and cell stratum concepts of Biology.

CONCLUSION

Based on the findings of this study the following conclusions were made:

1. Programmed instruction is an effective and reliable instructional strategy for improving students' academic performance and retention in Microscopy and cell stratum concepts of Biology.
2. The structured, step-by-step nature of programmed instruction, coupled with immediate feedback and self-paced learning, enables students to actively engage with practical content and achieve mastery in Microscopy and cell stratum concepts of Biology.
3. The conventional teaching method, which is predominantly lecture-based and teacher-centered, is less effective in promoting deep understanding and long-term retention in Microscopy and cell stratum concepts of Biology.

RECOMMENDATIONS

Based on the findings and conclusions of this study, the following recommendations are made:

Corresponding author: Safiyanu Musa
safiyanumusa74@gmai.com
Institute of Education, Ahmadu Bello University, Zaria.

1. Biology teachers should adopt programmed instruction in the teaching of Microscopy and cell stratum aspect of Biology practical topics, as it has been shown to significantly improve students' academic performance and retention.
2. Curriculum planners and developers, such as the Nigerian Educational Research and Development Council (NERDC), should incorporate programmed instruction strategy into the Biology curriculum and teacher guides to encourage learner-centered teaching approaches.
3. Government and educational stakeholders should provide adequate programmed learning packages, to support the effective implementation of programmed instruction in secondary schools.

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Corresponding author: Safiyanu Musa
safiyanumusa74@gmai.com
Institute of Education, Ahmadu Bello University, Zaria.