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Improving Biology Achievement Among Serialist Learners using a Jigsaw-Enriched Polya Problem-Solving Model: Evidence from Secondary Schools in Zaria, Nigeria

Muhammad Hayatu Yusuf* and Janet Funke Jesulowo

Department of Science Education, Ahmadu Bello University, Zaria, Kaduna State, Nigeria

***Corresponding author: mhayatuyusuf@abu.edu.ng**

Abstract

This study investigated the effectiveness of a Jigsaw-Enriched Polya Problem-Solving Model in improving Biology achievement among serialist learners in secondary schools in Zaria, Nigeria. The study was motivated by the persistent poor achievement of students in Biology and the need for innovative instructional approaches that accommodate learners' cognitive preferences while promoting active participation and problem-solving skills. The study employed a quasi-experimental pretest-posttest control group design. The population comprised 7,097 Senior Secondary School II (SS II) Biology students from 30 public secondary schools in Zaria Education Zone, Kaduna State. A sample of 79 students was selected from two purposively chosen co-educational schools. The Learning Style Inventory (LSI) was used to identify serialist learners, while the Biology Concepts Performance Test (BCPT) served as the achievement measure with reliability coefficient of 0.86 determined using Pearson Product Moment (PPM). Students in the experimental group were taught using the Jigsaw-Enriched Polya Problem-Solving Model, whereas those in the control group were taught using the Conventional Method. Data were analyzed using mean, standard deviation, and Analysis of Covariance (ANCOVA) at a 0.05 level of significance. Findings revealed that serialist learners exposed to the Jigsaw-Enriched Polya Problem-Solving Model obtained a higher mean Biology achievement score (M = 59.39, SD = 15.58) than those taught using the Conventional Method (M = 50.84, SD = 15.16), with a mean difference of 8.55. Analysis of Covariance (ANCOVA) results further indicated a statistically significant difference between the mean Biology achievement scores of the two groups, $F(1, 76) = 83.61$, $p < .001$, partial $\eta^2 = .524$. Consequently, the null hypothesis, which stated that there is no significant difference between the mean Biology achievement scores of secondary school serialist learners taught using the Jigsaw-Enriched Polya Problem-Solving Model and those taught using the Conventional Method, was rejected. The study concluded that the Jigsaw-Enriched Polya Problem-Solving Model significantly enhances the Biology achievement of serialist learners and is more effective than the Conventional Method. The study recommends that Biology teachers adopt the model as an instructional strategy for improving students' achievement and promoting meaningful learning in secondary school Biology classrooms.

Keywords: biology achievement, serialist learners, jigsaw cooperative learning, Polya problem-solving model, secondary school students

1 Introduction

Biology occupies a strategic position in secondary school science education because it provides learners with essential knowledge and skills for understanding living organisms, environmental sustainability, health, agriculture, and biotechnology. In Nigeria, Biology remains one of the most popular science subjects at the senior secondary school level and serves as a prerequisite for admission into numerous science-based professions such as medicine, pharmacy, nursing, agriculture, and environmental sciences. Despite its significance, students' achievement in Biology has remained relatively low, as evidenced by reports from external examination bodies and educational researchers. The persistent poor performance has been attributed to factors such as inadequate instructional methods, poor problem-solving skills, limited student engagement, and overreliance on conventional teacher-centered approaches that emphasize rote memorization rather than meaningful learning (Awoyeye & Apochi, 2026; Siloko & Oyovwi, 2024).

The increasing demand for scientific literacy and twenty-first-century competencies has led educators to advocate for learner-centered instructional approaches that actively engage students in the learning process. Such approaches promote critical thinking, collaboration, communication, creativity, and problem-solving skills necessary for effective learning and academic success. Contemporary science education emphasizes the need for learners to construct knowledge through active participation rather than passively receive information from teachers. Research has consistently shown that active learning strategies improve students' conceptual understanding, achievement, retention, and motivation in science subjects (Vojinović et al., 2023). Among the pedagogical approaches designed to enhance learners' problem-solving abilities is Polya's Problem-Solving Model. Developed by George Polya (1957), the model consists of four systematic stages: understanding the problem, devising a plan, carrying out the plan, and reviewing the solution. The model encourages learners to approach problems logically and analytically while developing reflective thinking skills. Although the model was originally developed for mathematics education, it has increasingly been adopted in science education because of its effectiveness in helping learners solve complex scientific problems and improve conceptual understanding. Studies have reported that students exposed to Polya's problem-solving strategy demonstrate higher achievement and retention than those taught using traditional instructional methods (Polya, 1957; Siloko & Oyovwi, 2024; Awoyeye & Apochi, 2026).

Another learner-centered strategy that has gained considerable recognition in science education is the Jigsaw cooperative learning technique. The Jigsaw strategy, developed by Aronson (1978), is based on the principle of cooperative learning where students work together in small groups to achieve shared learning goals. Under this approach, each learner becomes responsible for mastering a specific segment of the learning material and subsequently teaching it to other members of the group. This process promotes positive interdependence, accountability, communication, and active participation among learners. Empirical studies have shown that the Jigsaw method enhances students' academic achievement, motivation, retention, and social interaction in science classrooms. For instance, Kebede et al. (2025) reported a significant improvement in Biology achievement among students taught using the Jigsaw cooperative learning strategy compared to those exposed to conventional instructional approaches. While instructional strategies play a significant role in determining students' academic achievement, individual differences in learning styles also influence how learners process, organize, and retain information. One of the prominent theories explaining such differences is Pask's Learning Style Theory, which categorizes learners into serialists and holists (Pask, 1976). Serialist learners prefer learning in a logical, sequential, and step-by-step manner. They focus on mastering individual concepts before connecting them to broader ideas. Such learners often perform well when instructional activities are highly structured and systematically organized. However, they may encounter difficulties when required to integrate multiple concepts simultaneously, a common requirement in Biology learning where concepts are interconnected and often abstract (Pask, 1976).

Given the unique characteristics of serialist learners, there is a need for instructional approaches that combine structured problem-solving procedures with collaborative opportunities that facilitate knowledge construction. Integrating the Jigsaw cooperative learning technique with Polya's Problem-Solving Model appears to offer such an opportunity. The structured stages of Polya's model align with the sequential learning preference of serialist learners, while the collaborative nature of Jigsaw learning promotes peer interaction, discussion, and shared responsibility for learning. This integration may enable learners to process biological concepts systematically while simultaneously benefiting from cooperative knowledge exchange and multiple perspectives during problem-solving activities. The theoretical foundation for integrating Jigsaw and Polya's model can be explained through constructivist learning theory and social interdependence theory. Constructivist theory posits that learners actively construct knowledge through interaction with their environment and peers (Vygotsky, 1978). Similarly, social interdependence theory emphasizes that cooperative learning environments foster positive interactions that enhance academic achievement (Johnson & Johnson, 2009). Consequently, a Jigsaw-enriched Polya Problem-Solving Model may create a learning environment that supports both cognitive and social dimensions of learning, thereby improving students' understanding and achievement in Biology.

In the Nigerian context, particularly in Zaria, Kaduna State, efforts to improve students' achievement in Biology continue to attract attention from researchers and educational stakeholders. Although previous studies have independently examined the effectiveness of Polya's problem-solving strategy and Jigsaw cooperative learning in improving academic performance, limited empirical evidence exists regarding the combined use of these two approaches, especially among serialist learners in secondary school Biology classrooms. Furthermore, little is known about the extent to which a Jigsaw-enriched Polya Problem-Solving Model can enhance Biology achievement among serialist learners within the socio-cultural and educational setting of Zaria. This gap necessitates empirical investigation. Therefore, this study investigates the effectiveness of a Jigsaw-Enriched Polya Problem-Solving Model in improving Biology achievement among serialist learners in secondary schools in Zaria, Nigeria. Specifically, the main objective of this study focused toward improving Biology achievement among serialist learners using a jigsaw-enriched Polya Problem-Solving Model: evidence from secondary schools in Zaria, Nigeria. The study also is set to address the research question that states thus: what is the difference between the mean Biology achievement scores of secondary schools serialist learners in Zaria taught using Jigsaw-Enriched Polya Problem-Solving Model and those taught using Conventional Method?

2 Literature Review/ Theoretical Framework

A persistent concern in contemporary science education is the relatively low level of students' achievement in Biology despite the subject's strategic importance for developing scientific literacy and preparing learners for careers in medicine, agriculture, biotechnology, environmental science, and other life science disciplines. Biology requires students to integrate conceptual understanding with scientific inquiry, critical thinking, and problem-solving; however, classroom instruction in many developing countries continues to be dominated by conventional lecture methods that encourage passive learning and memorization rather than active knowledge construction. Consequently, students frequently experience difficulties in understanding abstract biological concepts, applying scientific principles to authentic situations, and retaining learned content. Recent educational research consistently argues that learner-centred instructional approaches capable of promoting active participation, collaborative inquiry, and reflective thinking produce more meaningful learning outcomes than traditional teacher-centred pedagogies. These findings have intensified interest in innovative instructional models that simultaneously enhance cognitive engagement, social interaction, and academic achievement among secondary school Biology students

Among learner-centred pedagogies, cooperative learning has emerged as one of the most extensively researched instructional approaches for improving students' academic performance across science disciplines. Cooperative learning restructures classroom activities by encouraging learners to work collaboratively toward shared academic goals while maintaining individual accountability for learning. Within this family of instructional approaches, the Jigsaw strategy has attracted considerable scholarly attention because of its unique organisation, whereby students become "experts" on different segments of instructional content before teaching those segments to their peers. This reciprocal teaching process promotes active engagement, collaborative reasoning, communication, and shared responsibility for learning. A recent systematic review synthesising more than four decades of Jigsaw research concluded that the strategy generally improves academic performance and psychosocial outcomes, although the magnitude of its effectiveness varies according to implementation quality, classroom context, and subject domain (Vives et al., 2025). Likewise, a comprehensive systematic review and meta-analysis involving sixty-nine empirical studies reported that Jigsaw instruction positively influences students' academic achievement, motivation, and social interaction while promoting inclusive classroom environments that support deeper conceptual learning (Cochon Drouet et al., 2023). These reviews further emphasize that the educational benefits of Jigsaw become more pronounced when learners actively engage in explaining concepts, negotiating meanings, and solving authentic learning tasks collaboratively rather than merely exchanging factual information.

Recent empirical evidence from Biology classrooms further substantiates the instructional value of Jigsaw cooperative learning. Using a quasi-experimental pretest-posttest design involving secondary school students in Ethiopia, Kebede et al. (2025) demonstrated that learners exposed to Jigsaw cooperative learning significantly outperformed their counterparts taught through conventional instruction in Biology achievement. The study attributed these improvements to increased learner engagement, collaborative problem-solving, peer teaching, and greater accountability during classroom activities. Interestingly, although the intervention significantly enhanced overall Biology achievement, no statistically significant gender difference was observed within the experimental group, suggesting that the instructional benefits of Jigsaw are broadly applicable across male and female learners. These findings strengthen the argument that cooperative learning environments provide opportunities for learners to construct scientific knowledge collectively while simultaneously developing communication and critical thinking skills that support higher academic achievement.

The effectiveness of cooperative learning is further reinforced by evidence from recent systematic reviews conducted in other educational disciplines. For example, a ScienceDirect meta-analysis examining the Jigsaw technique across nursing education reported significant improvements in students' academic achievement, critical thinking, communication skills, motivation, self-confidence, and collaborative competence compared with traditional instructional approaches (Özkan & Çetinkaya Uslusoy, 2024). Similarly, qualitative investigations have shown that integrating Jigsaw with complementary learner-centred strategies such as concept mapping and collaborative group activities enhances students' learning confidence, reflective thinking, and perceived learning effectiveness by creating positive cycles of peer interaction and self-evaluation (Lin et al., 2025). Although these studies were conducted outside Biology education, they provide compelling evidence that Jigsaw promotes learning through mechanisms that are transferable across educational contexts, including collaborative reasoning, active participation, and shared cognitive responsibility

While cooperative learning primarily addresses the social dimension of learning, effective Biology instruction equally requires structured cognitive support that enables students to solve scientific problems systematically. Problem-solving occupies a central position within science education because biological understanding depends not merely on recalling scientific facts but on analysing relationships, interpreting evidence, formulating explanations, and evaluating alternative solutions. Among structured problem-solving frameworks, the Polya Problem-Solving Model remains one of the most influential instructional models because it organises learning into four sequential stages: understanding the problem, devising a plan, carrying out the plan, and looking back. These stages encourage learners to regulate their thinking, monitor solution processes, evaluate outcomes, and transfer acquired knowledge to unfamiliar situations. Contemporary educational research increasingly recognises structured problem-solving as an effective means of promoting conceptual understanding, metacognition, and higher-order thinking because it transforms learners from passive recipients of information into active constructors of scientific knowledge.

Despite the documented effectiveness of Jigsaw cooperative learning and structured problem-solving when implemented independently, relatively little empirical attention has been devoted to instructional models that intentionally integrate these complementary pedagogical approaches. Conceptually, such integration is educationally compelling because the Polya model provides learners with a systematic cognitive framework for analyzing scientific problems, whereas the Jigsaw strategy creates collaborative learning environments through which learners collectively construct, evaluate, and refine scientific understanding. The resulting instructional synergy is expected to enhance conceptual processing, reflective thinking, scientific communication, and collaborative inquiry more effectively than either approach implemented in isolation. Contemporary scholarship increasingly recommends combining multiple evidence-based learner-centred strategies to address the multidimensional nature of scientific learning rather than relying on single instructional interventions.

The effectiveness of integrated instructional approaches may become even more pronounced when learners' cognitive characteristics are considered. According to Pask's theory of learning strategies, serialist learners characteristically prefer sequential, logical, and stepwise processing of information. Such learners construct understanding gradually by progressing through carefully organized instructional sequences and often experience difficulty when confronted with fragmented or poorly structured learning experiences. Conventional lecture methods rarely accommodate these preferences because they encourage passive reception of information without sufficient opportunities for systematic reasoning, collaborative exploration, or reflective evaluation. In contrast, integrating Polya's sequential problem-solving framework with Jigsaw cooperative learning appears particularly compatible with serialist learners because it combines structured cognitive progression with collaborative discussion, peer explanation, and guided reflection. This instructional alignment may therefore enhance conceptual understanding, improve Biology achievement, and promote meaningful learning among learners who naturally favour sequential information processing.

Although international research increasingly supports learner-centred pedagogies for improving science achievement, several important gaps remain within the literature. First, most contemporary studies have examined Jigsaw cooperative learning or structured problem-solving independently, whereas relatively few investigations have evaluated instructional models that deliberately integrate both approaches into a unified pedagogical framework. Second, existing studies have predominantly focused on general student populations without examining whether instructional effectiveness varies according to learners' cognitive styles, particularly the serialist–holist dimension. Third, despite continuing concerns regarding students' achievement in Biology across sub-Saharan Africa, empirical evidence from Nigerian secondary schools remains comparatively limited. Finally, ecology represents one of the most conceptually demanding topics within secondary Biology because it requires learners to analyze complex interactions among organisms and their environments using systematic scientific reasoning. Yet relatively few recent studies have investigated how integrated cooperative problem-solving approaches influence Biology achievement within this instructional context. Addressing these gaps, the present study investigates whether a Jigsaw-Enriched Polya Problem-Solving Model can improve Biology achievement among serialist learners in secondary schools in Zaria, Nigeria, thereby extending current evidence on learner-centred science instruction while contributing context-specific findings relevant to Biology education in developing countries.

This study is anchored on Bruner's Discovery Learning Theory (1961), Riding's Cognitive Style Theory (1991), and Vygotsky's Social Constructivist Theory (1978). Collectively, these theories provide a strong conceptual foundation for understanding how a Jigsaw-Enriched Polya Problem-Solving Model can enhance Biology achievement among serialist learners in secondary schools. Bruner's Discovery Learning Theory posits that meaningful learning occurs when students actively construct knowledge through exploration, inquiry, and problem-solving rather than passively receiving information from the teacher. According to Bruner (1961), learners develop deeper understanding and longer retention when they discover relationships and concepts independently by drawing on prior knowledge and interacting with learning materials. The Polya Problem-Solving Model reflects this principle by engaging students in a systematic process of understanding biological problems, devising solution strategies, implementing those strategies, and evaluating outcomes. Through these structured inquiry activities, students actively participate in constructing biological knowledge, thereby promoting meaningful learning and improved academic achievement.

The study is further underpinned by Riding's Cognitive Style Theory (1991), particularly the Serialist–Holist dimension, which explains individual differences in information processing. Riding argues that serialist learners prefer information presented in a logical, sequential, and step-by-step manner, whereas holistic learners tend to process information globally before examining details. This theoretical perspective is especially relevant because the present study specifically focuses on serialist learners. The sequential stages of Polya's Problem-Solving Model closely correspond with the learning preferences of serialist students by providing organised and systematic procedures for solving Biology problems. Consequently, integrating Polya's structured problem-solving approach with Jigsaw cooperative learning is expected to create an instructional environment that aligns with serialist learners' cognitive preferences, thereby facilitating improved understanding and higher Biology achievement.

The study also draws on Vygotsky's Social Constructivist Theory (1978), which emphasizes that learning is fundamentally a social process occurring through interaction with more knowledgeable peers and teachers. Vygotsky maintained that learners develop higher cognitive abilities through collaborative activities within the Zone of Proximal Development, where peer support and teacher guidance facilitate knowledge construction. The Jigsaw component of the instructional model operationalizes this theory by organising students into cooperative learning groups in which each member assumes responsibility for mastering and teaching a portion of the learning content. Through peer explanation, discussion, questioning, and collaborative problem-solving, students actively construct biological concepts while developing communication, critical thinking, and reasoning skills. The integration of Jigsaw with Polya's structured problem-solving process therefore combines cognitive engagement with collaborative learning, enabling students to solve biological problems collectively while deepening conceptual understanding. Together, these three theories complement one another in explaining the effectiveness of the Jigsaw-Enriched Polya Problem-Solving Model. Bruner's theory provides the basis for inquiry and knowledge discovery, Riding's theory explains why the structured, sequential nature of the model is particularly appropriate for serialist learners, and Vygotsky's theory justifies the collaborative learning environment created through Jigsaw. Their integration offers a comprehensive theoretical explanation for how structured problem-solving and cooperative learning can improve Biology achievement among serialist learners. Accordingly, these theories provide the conceptual basis for investigating the effectiveness of the Jigsaw-Enriched Polya Problem-Solving Model in enhancing Biology achievement among secondary school serialist learners in Zaria, Nigeria.

3 Methodology

3.1 Research Design

This study adopted a quasi-experimental pretest–posttest control group design involving intact SS II Biology classes in public secondary schools within the Zaria Education Zone, Kaduna State, Nigeria. The design was considered appropriate because random assignment of individual students to treatment conditions was impracticable in the school setting. Consequently, intact classes were used to preserve normal school organization while minimizing disruption to instructional activities. The experimental group was taught Ecology using the Jigsaw-Enriched Polya Problem-Solving Model, whereas the control group received instruction through the Conventional Lecture Method. A pretest was administered before the commencement of the intervention to establish baseline equivalence between the groups, while a posttest was conducted after the six-week instructional period to determine the effect of the treatment on students' Biology achievement.

3.2 Sample and Sampling Procedure

The study population comprised all Senior Secondary School II (SS II) Biology students (N = 7,097) enrolled in 30 public senior secondary schools in the Zaria Education Zone, Kaduna State, Nigeria. A multistage sampling procedure was employed. In the first stage, four co-educational public secondary schools were selected through simple random sampling from the eligible schools in the zone. To ensure baseline comparability and strengthen the internal validity of the quasi-experimental design, the selected schools participated in a pretest using the Biology Concepts Performance Test (BCPT). The pretest scores were analyzed using one-way Analysis of Variance (ANOVA), followed by Scheffé post hoc comparisons. The analysis indicated that two schools did not differ significantly in their pretest mean achievement scores ($p > .05$) and were therefore considered equivalent at baseline. These two comparable schools were purposively retained and randomly assigned to the experimental and control groups, while the remaining two schools were excluded because they did not satisfy the equivalence criterion.

The two selected schools comprised a total of 125 SS II Biology students, distributed into an experimental group (63 students) and a control group (62 students). Students were subsequently classified into serialist and holistic learning styles using the Learning Style Inventory (LSI) adapted from Riding and Cheema's Cognitive Styles Analysis (1991). The LSI consisted of 10 multiple-choice items, each containing two response alternatives (A and B) representing serialist and holistic learning preferences, respectively. Prior to administration, the instrument was subjected to face and content validation by experts in Science Education and Educational Psychology to ensure its suitability for the study. Students were categorized according to their dominant response pattern: those selecting alternative A more frequently than alternative B were classified as serialist learners, whereas those selecting alternative B more frequently were classified as holistic learners. Since the focus of this study was on serialist learners, only the 79 students identified as serialists (41 in the experimental group and 38 in the control group) were included in the final data analysis to control for the influence of cognitive style on Biology achievement. Summary of the participants was represented in Table 1.

Table **1**

Distribution of Participants by Group, Gender, and Learning Style

S/N	Group	Serialist (Male)	Serialist (Female)	Holistic (Male)	Holistic (Female)	Total
1	Experimental	23	18	12	10	63
2	Control	18	20	13	11	62
Total		**41**	**38**	**25**	**21**	**125**

As shown in Table 1, the initial sample comprised 125 students, of whom 79 were identified as serialist learners (41 in the experimental group and 38 in the control group). These serialist learners constituted the effective sample for the present study, while the holistic learners were excluded from the statistical analyses because the investigation specifically examined the effectiveness of the Jigsaw-Enriched Polya Problem-Solving Model among serialist learners.

3.3 Method of Data Collection

Data were collected using two instruments: the Learning Style Inventory (LSI) and the Biology Concepts Performance Test (BCPT). The LSI with reliability coefficient of 0.79 estimated using Kuder–Richardson Formula 20 (KR-20) was administered before the intervention to classify students into serialist and holistic learning styles, whereas the BCPT served as both the pretest and posttest measure of Biology achievement. The LSI and BCPT were subjected to face and content validation by specialists in Science Education and Educational Psychology. The reliability coefficient of the BCPT was established at 0.86 using the Pearson Product Moment Correlation (PPMC), indicating that the instrument was sufficiently reliable for educational research. Following the administration of the pretest, the experimental group received instruction using the Jigsaw-Enriched Polya Problem-Solving Model, while the control group was taught the same Biology concepts using the Conventional Lecture Method. The instructional intervention lasted six weeks, after which the BCPT was re-administered as the posttest.

3.4 Method of Data Analysis

The data collected were analyzed using both descriptive and inferential statistics. Descriptive statistics, including mean, standard deviation, and mean difference, were used to answer the research question by summarizing the Biology achievement scores of serialist learners in the experimental and control groups. To test the null hypothesis, an analysis of covariance (ANCOVA) was employed at the 0.05 level of significance to determine whether a statistically significant difference existed in the Biology achievement scores of serialist learners exposed to the Jigsaw-Enriched Polya Problem-Solving Model and those taught using the Conventional Method, while controlling for their pretest achievement scores.

The statistical analysis was performed using IBM SPSS Statistics, and all decisions regarding hypothesis testing were based on the criterion of $p \leq .05$.

4 Results

Research Question: What is the difference between the mean Biology achievement scores of secondary school serialist learners in Zaria taught using Jigsaw-Enriched Polya Problem-Solving Model and those taught using Conventional Method?

To answer this research question, descriptive analysis involving mean and standard deviation was used. The result of the analysis is presented in Table 2

Table **2**

Mean and Standard Deviation of Biology Achievement Scores of Secondary School Serialist Learners Taught Using Jigsaw-Enriched Polya Problem-Solving Model and Conventional Method

Groups	*n*	*M*	*SD*	Mean Difference
Experimental	41	59.39	15.58	8.55
Control	38	50.84	15.16	

Table 2 descriptive mean statistics shows that there is a difference between the mean Biology achievement scores of secondary school serialist learners taught using the Jigsaw-Enriched Polya Problem-Solving Model and those taught using the Conventional Method. The computed mean Biology achievement scores are 59.39 and 50.84 for secondary school serialist learners taught using the Jigsaw-Enriched Polya Problem-Solving Model and those taught using the Conventional Method respectively with a mean difference of 8.55. This shows that serialist learners taught using the Jigsaw-Enriched Polya Problem-Solving Model had higher mean Biology achievement scores than those taught using the Conventional Method.

Null hypothesis: There is no significant difference between the mean Biology achievement scores of secondary school serialist learners in Zaria taught using the Jigsaw-Enriched Polya Problem-Solving Model and those taught using the Conventional Method.

To test this null hypothesis, the pre-test and posttest Biology achievement scores of secondary school serialist learners in the experimental and control groups were subjected to Analysis of Covariance ANCOVA statistics and summary of the analysis is presented in Table 3.

Table **3**

Summary of ANCOVA of Biology Achievement Scores of Serialist Learners by Instructional Method

Source	Type III SS	*df*	MS	*F*	*p*	Partial η^2
Pretest	950.59	1	950.59	11.81	.001	.134
Instructional method	6,730.36	1	6,730.36	83.61	< .001	.524
Error	6,117.60	76	80.49	—	—	—
Corrected total	13,914.71	78	—	—	—	—

The results in Table 3 show that, after controlling for pretest Biology achievement scores, there was a statistically significant difference in the posttest Biology achievement scores of serialist learners based on instructional method, $F(1, 76) = 83.61$, $p < .001$, partial $\eta^2 = .524$. The partial eta squared indicates a large effect of instructional method on Biology achievement. Therefore, the null hypothesis that there is no significant difference between the mean Biology achievement scores of serialist learners taught using the Jigsaw-Enriched Polya Problem-Solving Model and those taught using the Conventional Method is rejected. The finding indicates that the Jigsaw-Enriched Polya Problem-Solving Model produced significantly higher Biology achievement among serialist learners than the Conventional Method, after controlling for differences in pretest scores.

5 Discussion of Findings

The study investigated the effect of a Jigsaw-Enriched Polya Problem-Solving Model on the Biology achievement of serialist learners in secondary schools in Zaria, Nigeria. The findings revealed a substantial difference in the mean achievement scores of serialist learners exposed to the Jigsaw-Enriched Polya Problem-Solving Model and those taught using the Conventional Method. Specifically, serialist learners in the experimental group obtained a mean score of 59.39, while their counterparts in the control group recorded a mean score of 50.84, resulting in a mean difference of 8.55. This finding indicates that the Jigsaw-Enriched Polya Problem-Solving Model was more effective in improving students' achievement in Biology than the conventional lecture approach.

The inferential analysis provided stronger evidence for the effectiveness of the instructional model. Analysis of covariance (ANCOVA), conducted after controlling for students' pretest Biology achievement scores, revealed a statistically significant effect of instructional method on the posttest achievement scores of serialist learners, $F(1, 76) = 83.61$, $p < .001$, partial $\eta^2 = .524$. Thus, the null hypothesis stating that there was no significant difference between the mean Biology achievement scores of serialist learners taught using the Jigsaw-Enriched Polya Problem-Solving Model and those taught using the Conventional Method was rejected. The partial eta squared value of .524 indicates a large effect, suggesting that instructional method accounted for a substantial proportion of the variance in Biology achievement after controlling for pre-existing differences in students' achievement. The significant pretest effect, $F(1, 76) = 11.81$, $p = .001$, further justifies the use of ANCOVA because students' initial achievement levels were significantly related to their posttest performance.

The superior performance of serialist learners exposed to the treatment may be attributed to the complementary strengths of the two instructional approaches integrated in the model. Polya's Problem-Solving Model provides learners with a structured and sequential framework for approaching biological problems through understanding the problem, devising a plan, implementing the plan, and evaluating the solution. Such an orderly learning process is consistent with the cognitive preferences of serialist learners who tend to process information in a step-by-step manner. The model therefore enabled learners to organize biological concepts systematically, thereby enhancing understanding and achievement. Furthermore, the integration of the Jigsaw cooperative learning strategy appears to have strengthened the effectiveness of Polya's approach by creating opportunities for peer interaction, collaborative learning, knowledge sharing, and active participation. Through expert and home group discussions, learners were able to explain concepts to one another, clarify misconceptions, and collectively solve Biology-related problems. This collaborative process likely enhanced conceptual understanding and promoted deeper learning, resulting in higher academic achievement among the experimental group.

The findings of the present study are consistent with the work of Siloko and Oyovwi (2024), who reported that students exposed to Polya's problem-solving strategy achieved significantly higher scores in Biology than those taught using conventional methods. The result also supports the findings of Awoyeye and Apochi (2026), who found that the use of Polya-based instructional strategies significantly improved students' achievement and interest in Biology. These studies suggest that structured problem-solving approaches enhance learners' ability to understand and apply scientific concepts effectively. The findings are also in agreement with those of Kebede et al. (2025), who found that students taught using the Jigsaw cooperative learning strategy performed significantly better than students taught through traditional instructional methods. Similarly, Ogbiku and Ajaja (2024) reported improved achievement and retention among Biology students exposed to Jigsaw cooperative learning. The consistency between the present study and previous empirical evidence suggests that cooperative learning environments facilitate active engagement, accountability, and meaningful learning experiences that contribute positively to academic performance.

From a theoretical perspective, the findings support Constructivist Learning Theory, which posits that meaningful learning occurs when learners actively construct knowledge through interaction with their environment and peers. The results also validate Social Interdependence Theory, which emphasizes that cooperative learning promotes positive interaction and shared responsibility, leading to improved learning outcomes. The Jigsaw-Enriched Polya Problem-Solving Model effectively combined these cognitive and social learning principles to enhance Biology achievement among serialist learners. Overall, the findings indicate that instructional approaches that simultaneously address learners' cognitive preferences and collaborative learning needs can significantly improve Biology achievement. The study therefore demonstrates that the Jigsaw-Enriched Polya Problem-Solving Model provides a more effective instructional alternative than the Conventional Method for enhancing the academic achievement of serialist learners in secondary school Biology.

6 Conclusion

Based on the findings of this study, it is concluded that the Jigsaw-Enriched Polya Problem-Solving Model significantly improves the Biology achievement of serialist learners in secondary schools in Zaria, Nigeria. Serialist learners taught using the model performed significantly better than those taught through the Conventional Method. The model's effectiveness can be attributed to its ability to combine the structured, sequential learning processes preferred by serialist learners with the interactive and collaborative features of Jigsaw cooperative learning. The study further concludes that integrating problem-solving and cooperative learning approaches provides an effective instructional framework for promoting active engagement, critical thinking, conceptual understanding, and academic achievement in Biology. Consequently, the Jigsaw-Enriched Polya Problem-Solving Model represents an innovative and pedagogically sound strategy capable of addressing persistent challenges associated with students' achievement in Biology, particularly among learners with serialist cognitive characteristics.

7. Recommendations

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

1. Biology teachers should adopt the Jigsaw-Enriched Polya Problem-Solving Model as an instructional strategy for teaching Biology concepts in secondary schools because of its demonstrated effectiveness in improving students' academic achievement.
2. Teacher education institutions and professional development agencies should organize workshops, seminars, and in-service training programmes to equip Biology teachers with the skills required for implementing Jigsaw cooperative learning and Polya problem-solving strategies effectively.
3. Curriculum developers and educational policymakers should incorporate problem-solving and cooperative learning strategies into Biology curricula and instructional guidelines to promote active learning and improved academic achievement.
4. School administrators should provide adequate support, instructional resources, and conducive classroom environments that facilitate collaborative learning and problem-solving activities among students.
5. Biology teachers should consider learners' cognitive characteristics, particularly serialist learning preferences, when planning instruction to ensure that teaching approaches align with students' learning needs and maximize learning outcomes.
6. Further studies should be conducted in other science subjects, educational levels, and geographical locations to determine the generalizability of the effectiveness of the Jigsaw-Enriched Polya Problem-Solving Model beyond Biology classrooms and the Zaria educational context.

7 Declarations

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