EFFECT OF POLYA'S - PROBLEM-SOLVING MODEL ENRICHED WITH JIGSAW -COOPERATIVE LEARNING ON THE ACQUISITION OF SCIENCE PROCESS - SKILLS AMONG HOLISTIC SECONDARY SCHOOL BIOLOGY STUDENTS; ZARIA, NIGERIA

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Abstract

This study investigated the effectiveness of Polya's Problem-Solving Model enriched with Jigsaw Cooperative Learning on the acquisition of science process skills (SPS) among holistic senior secondary school Biology students in Zaria, Nigeria. A quasi-experimental pretest–posttest control group design was employed. The population comprised all 7,097 SS2 Biology students from 30 public Senior Secondary Schools in Zaria Education Zone, out of which 125 SS II Biology students (66 males, 59 females) drawn from two purposively selected co-educational schools made up the sample of the study. Two validated instruments were used in the study. The one used for categorizing the students based on their Learning Styles was the Learning Style Inventory (LSI) while the other used for data collection was the Science Process Skills Acquisition Test (SPSAT) with reliability coefficients of 0.84, estimated using Pearson Product-Moment Correlation Coefficient (PPMCC) statistics. The experimental group received instruction using the Polya's-Problem-Solving Model Enriched with Jigsaw-Cooperative Learning, while the control group was taught using conventional lecture method. Data were collected using the Science Process Skills Acquisition Test (SPSAT) and analyzed with descriptive statistics and Analysis of Variance (ANOVA) at a 0.05 significance level. Results revealed that students exposed to the polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning instructional strategy significantly outperformed their peers in SPS acquisition ($F(1,123) = 232.15$, $p < 0.001$, $\eta^2 = 0.66$), indicating a very large effect. Additionally, no significant gender differences were observed among holistic

learners ($F(1,39) = 0.52$, $p = 0.47$, $\eta^2 = 0.01$), suggesting that the instructional strategy is equally effective for male and female students. The findings underscore the value of integrating structured problem-solving with cooperative learning to enhance inquiry-based skills, engagement, and conceptual understanding in secondary Biology education.

Keywords: *Polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning strategy, Science process skills, Cooperative learning, Problem-solving instruction, Holistic learners, Secondary school Biology, Gender differences.*

Introduction

Biology is a core science subject at both secondary and tertiary levels of education in Nigeria, concerned with the study of living organisms, their structures, functions, interactions, and adaptations. Its relevance to national development is underscored by its foundational role in applied disciplines such as Medicine, Agriculture, Nursing, and Biotechnology. Consequently, the Federal Ministry of Education recognizes Biology as a compulsory subject at the senior secondary school level, aimed at equipping learners with scientific knowledge, practical competencies, and problem-solving abilities necessary for real-life applications (FME, 2013; NERDC, 2017; Usman, 2021).

Despite this importance, students' achievement in Biology in external examinations conducted by the West African Examinations Council remains persistently low. Research evidence attributes this trend to the abstract nature of key topics such as Ecology, Genetics, and Cell Physiology, as well as the continued reliance on teacher-centered instructional methods that limit active student engagement (Yetunde & Mutiat, 2021; Barbier & Burgess, 2022; Mpate, 2025). Ecology, in particular, involves complex relationships among organisms and their environments, requiring higher-order thinking and strong process skills, which many students struggle to develop effectively. Central to meaningful science learning is the acquisition of science process skills, which include basic skills such as observation, classification, measurement, and prediction, as well as integrated skills such as hypothesis formulation, experimentation, data interpretation, and conclusion drawing (Dolapçıoğlu & Subası, 2022; Fıtrıanı et al., 2020). These skills enable learners to engage in scientific inquiry and develop deep conceptual understanding. However, reports by WAEC (2022) indicate that many students demonstrate poor proficiency in these skills, particularly in practical Biology components, thereby contributing significantly to their low academic performance.

One major factor influencing this situation is the continued dominance of the conventional lecture method in Biology classrooms. This method is largely teacher-centered, emphasizing content delivery over student participation, and often fails to provide opportunities for hands-on investigation, collaboration, and critical thinking (Mpate, 2025). As a result, students become passive recipients of knowledge, limiting their ability to develop essential scientific skills and apply concepts meaningfully.

In response, educational researchers have advocated for the adoption of innovative, learner-centered instructional strategies that promote active engagement and problem-solving. Among these approaches, Polya's Problem-Solving Model has gained prominence. Developed by George Polya in 1957, the model outlines four systematic steps: understanding the problem, devising a plan, carrying out the plan, and looking back to evaluate the solution. When applied to science education, this model fosters logical reasoning, inquiry skills, and reflective thinking, all of which are essential for mastering complex Biology concepts.

Complementing this approach is Jigsaw Cooperative Learning, developed by Elliot Aronson in 1972. The Jigsaw strategy promotes cooperative learning by dividing instructional content into segments assigned to individual group members, who later teach their peers. This structure enhances interdependence, accountability, and active participation, while fostering communication and critical thinking skills. Integrating Jigsaw Cooperative Learning with Polya's Problem-Solving Model is expected to provide a synergistic effect, combining structured reasoning with collaborative engagement to enhance students' science process skills acquisition.

Another important variable influencing learning outcomes is cognitive style, particularly the holist–serialist dimension proposed by Gordon Pask (1976). Holistic learners prefer to process information globally, seeking meaningful connections among concepts before attending to details. They benefit from instructional environments that promote synthesis, conceptual integration, and collaborative sense-making. Instructional strategies that fragment learning excessively may constrain holistic learners' ability to construct coherent mental models, whereas approaches that encourage discussion, integration of perspectives, and reflection support their natural learning tendencies (Maitra & Srivastava, 2021; Lin & Wong, 2024).

In addition to cognitive style, gender has been widely examined as a moderating variable in science education. While some studies report differences in science achievement and process skills between male and female students, findings remain inconsistent across contexts (Lin & Wong, 2024; Mpate, 2025). This inconsistency highlights the need for further investigation into how instructional strategies interact with gender to influence learning outcomes.

Against this backdrop, the present study investigates the influence of Polya's Problem-Solving Model enriched with Jigsaw Cooperative Learning on the acquisition of science process skills among holistic Biology students in Zaria, Nigeria. It also examines the comparative effectiveness of this integrated approach relative to the conventional teaching method, while exploring the moderating effects of cognitive style and gender. The study aims to provide empirical evidence on innovative pedagogical practices capable of improving Biology teaching and learning, thereby addressing persistent challenges in students' performance and skill acquisition at the secondary school level.This study is anchored on Social Constructivist TheoryandCognitive Style Theory,

as proposed by Vygotsky (1978) and Riding (1991), respectively. These theories provide the most relevant and robust theoretical foundation for explaining how the Polya Problem-Solving Model enriched with Jigsaw Cooperative Learning influences science process skills acquisition among holistic secondary school Biology students.

Vygotsky's Social Constructivist Theory posits that learning is fundamentally a social process that occurs through interaction with others and is mediated by language, tools, and cultural context. Central to this theory is the concept of the Zone of Proximal Development (ZPD), which explains how learners can achieve higher cognitive outcomes when guided by teachers or more capable peers. In the present study, the Jigsaw Cooperative Learning strategy embedded within the Polya Problem-Solving Model operationalizes social constructivist principles by structuring learning around peer interaction, collaboration, and shared responsibility. Students work in expert and home groups to explore ecological problems, exchange ideas, test hypotheses, and collectively construct scientific understanding. Through these social interactions, learners actively engage in science process skills such as observing, predicting, experimenting, interpreting data, and drawing conclusions, thereby fostering deeper conceptual understanding and improved acquisition of science process-skills.

Cognitive Style Theory, as advanced by Riding (1991), provides a complementary framework for understanding individual differences in how learners process and organize information. Of particular relevance to this study is the holistic dimension of cognitive style. Holistic learners favor global processing and the integration of ideas into meaningful wholes. This theory explains why students may respond differently to the same instructional strategy and underscores the importance of aligning teaching methods with learners' cognitive processing preferences. The Polya Problem-Solving Model offers a systematic and sequential problem-solving structure that aligns well with holistic learners, while the Jigsaw Cooperative Learning component promotes holistic understanding through peer discussion, synthesis of ideas, and conceptual integration. Consequently, Cognitive Style Theory justifies the investigation of cognitive style as a moderating variable influencing students' science process skills acquisition.

Science process skills (SPS) are central to contemporary science education because they enable learners to engage in inquiry, generate evidence-based explanations, and apply scientific reasoning to real-world problems. SPS including observing, classifying, hypothesizing, experimenting, interpreting data, drawing conclusions, and communicating findings are widely regarded as core competencies for scientific literacy and lifelong learning in the 21st century (Dolapçıoğlu & Subası, 2022; OECD, 2023). Despite their importance, research consistently shows that many secondary school students demonstrate low proficiency in SPS, largely due to persistent reliance on teacher-centered instructional approaches that emphasize factual recall rather than inquiry and reasoning (NRC, 2022; Teig, Scherer, & Nilsen, 2024). Consequently, recent science education scholarship increasingly advocates for learner-centered instructional strategies that actively engage students in authentic scientific practices and cognitively demanding

learning tasks (Osborne, 2023; Kind & Llewellyn, 2024).

Problem-solving–oriented instructional approaches have received renewed attention in recent years for their effectiveness in promoting deep understanding and science process skills. Contemporary studies indicate that structured problem-solving models support learners' metacognitive regulation, analytical reasoning, and systematic inquiry, all of which are essential for SPS acquisition (Lazonder & Harmsen, 2023; Scherer, Teig, & Nilsen, 2022). In secondary science classrooms, problem-solving instruction has been shown to improve students' ability to formulate hypotheses, design investigations, interpret data, and transfer knowledge to unfamiliar contexts (Hmelo-Silver, 2022; Darling-Hammond et al., 2023). Recent Biology education research further demonstrates that problem-solving learning environments promote active engagement with ecological and biological systems, thereby strengthening students' inquiry behaviors and procedural understanding (Çimer & Coşkun, 2024; Mutlu & Şeşen, 2023).

Alongside problem-solving instruction, cooperative learning strategies particularly the Jigsaw method continue to attract strong empirical support for enhancing students' engagement, motivation, and learning outcomes. Recent meta-analyses and large-scale reviews confirm that cooperative learning significantly outperforms traditional lecture-based instruction in promoting achievement, higher-order thinking, and social interaction across science subjects (Slavin, 2023; Johnson & Johnson, 2024). The Jigsaw approach, which structures learning around positive interdependence and individual accountability, has been shown to enhance students' conceptual understanding, communication skills, and confidence by positioning learners as both knowledge constructors and peer instructors (Gillies, 2022; Tran & Lewis, 2024).

In science education contexts, recent empirical studies provide consistent evidence of the effectiveness of Jigsaw-based instruction. Studies conducted between 2022 and 2025 report that Jigsaw significantly improves students' academic performance, interest, and engagement in Biology and general science when compared with conventional teaching methods (Aydin & Yilmaz, 2023; Zakaria & Iksan, 2022). In African and other developing-country contexts, cooperative learning has been found to enhance students' science process skills by increasing opportunities for collaborative experimentation, discussion, data interpretation, and scientific argumentation (Ogunleye & Aina, 2023; Nwoye & Okeke, 2024). These findings suggest that structured peer collaboration provides authentic contexts for practicing and refining SPS.

Emerging literature further emphasizes that the instructional benefits of cooperative learning are amplified when integrated with structured cognitive frameworks such as problem-solving models. Recent studies indicate that combining cooperative strategies with explicit problem-solving scaffolds leads to greater gains in scientific reasoning, metacognitive awareness, and process-skill mastery than either approach used in isolation (Kirschner & Hendrick, 2022; Lazonder, Wilhelm, & Harmsen, 2024). Such blended instructional approaches align with contemporary constructivist and socio-cognitive perspectives, which view learning as an active process of knowledge

construction mediated through social interaction, dialogue, and guided inquiry (Gillies, 2022; Schunk & DiBenedetto, 2023).

Despite growing evidence supporting problem-solving and cooperative learning independently, recent reviews highlight a persistent gap in studies examining their combined effects on science process skills, particularly within secondary Biology education and specific content areas such as Ecology (Kind & Llewellyn, 2024; Teig et al., 2024). Furthermore, relatively few studies have explored how integrated instructional models interact with learner characteristics such as cognitive style and gender, even though recent evidence suggests that these variables can significantly moderate learning outcomes in science (Evans, Kirby, & Waring, 2023; Riding & Cheema, 2022). Many existing studies also prioritize achievement scores over process-oriented outcomes, limiting insights into how instructional strategies influence students' scientific practices.

Statement of the Problem

Students' persistent poor performance in Biology at the senior secondary school level has remained a major concern to parents, educators, and other stakeholders in Nigeria's education sector. Evidence from the West African Examinations Council (WAEC) Chief Examiners' Reports over a ten-year period (2014–2024) reveals consistently low acquisition of science process-skills in Biology, particularly in Ecology, among candidates in Kaduna State. Analysis of these reports shows that, on average, about two-thirds of candidates failed to obtain credit-level passes (A1–C6), thereby falling short of the minimum requirements for admission into science-related courses in higher institutions. This persistent trend indicates that Biology instruction has not been effective in promoting meaningful and lasting learning outcomes among secondary school students.

Research findings also have attributed the poor performance to several interrelated factors, among which ineffective instructional methods and poor acquisition of science process skills are prominent. Studies have shown that many Biology teachers rely heavily on traditional, teacher-centered approaches that provide limited opportunities for students to engage actively in scientific inquiry, problem solving, and hands-on learning. Consequently, students demonstrate weaknesses in essential science process skills such as observing, measuring, classifying, interpreting data, drawing conclusions, and communicating scientific findings. These deficiencies are evident in students' poor performance in practical Biology examinations, as consistently reported by WAEC, particularly in areas involving drawing, labeling, observation, experiment reporting, graph plotting, and data interpretation.

Science process skills are foundational to the construction of scientific knowledge and are critical for meaningful learning, problem-solving ability, and academic achievement in Biology. However, empirical studies conducted in Nigeria have consistently reported low levels of mastery of these skills among secondary school students, suggesting that current instructional practices are inadequate. In addition, Biology teachers often overlook

individual learner differences, especially cognitive styles such as serialistic and holistic learning preferences. The mismatch between students' cognitive processing styles and the instructional strategies employed in the classroom further compounds the problem, as teaching approaches that fail to align with learners' preferred modes of understanding can hinder the acquisition of science process skills and negatively affect academic performance.

Although several intervention studies have been conducted to improve students' science process skills acquisition in Biology but the problem persists, particularly in Ecology. This indicates the need for innovative, learner-centered instructional strategies that simultaneously promote problem solving, collaboration, and accommodation of learners' cognitive styles. One such approach is the integration of Polya's Problem-Solving Model with Jigsaw cooperative learning, which has the potential to foster structured reasoning, active participation, peer interaction, and reflective thinking.

Despite the theoretical promise of this integrated instructional approach, empirical evidence on its effectiveness in enhancing science process skills acquisition among holistic secondary school Biology students in Nigeria, particularly in the Zaria Education Zone of Kaduna State, remains limited. Therefore, the problem addressed by this study is whether the use of Polya's Problem-Solving Model enriched with Jigsaw instructional strategy can significantly improve science process skills acquisition in Ecology among senior secondary school students with holistic cognitive styles.

Objectives of the Study

The main objective of this study is to examine the effectiveness of Polya's Problem-Solving Model enriched with Jigsaw Cooperative Learning in enhancing science process skills among holistic senior secondary school Biology students in Zaria, Nigeria. Specifically, the study seeks to:

- Determine the effect of Polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning on the acquisition of science process skills in Ecology among holistic SS II Biology students;
- Investigate the effect of gender on science process skills acquisition among holistic SS Biology students taught Ecology using the Polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning.

Research Questions

The following research questions were formulated to guide the study:

1. What is the difference between the mean science process skills acquisition scores of holisticSS2 Biology students taught Ecology Concepts using Polya's-Problem-Solving Model Enriched with Jigsaw-Cooperative Learning and those taught the same concepts using Conventional Method?
2. What is the difference between the mean science process-skills acquisition scores

of holisticSS2 male and female Biology students taught ecology concept using Polya's-Problem-Solving Model Enriched with Jigsaw-Cooperative Learning?

Null Hypotheses

The following null hypotheses were formulated and tested at $p \leq 0.05$ level of significance:

H01: There is no significant difference between the mean science process skills acquisition scores in Ecology of holistic SS II Biology students taught using the Polya's–Jigsaw Model Enriched with Jigsaw-Cooperative Learning and those taught using the conventional teaching method.

H02: There is no significant difference between the mean science process skills acquisition scores in Ecology of male and female holistic SS II Biology students taught using the polya's -Problem-Solving Model Enriched with Jigsaw - Cooperative Learning Model Enriched with Jigsaw-Cooperative Learning.

Methodology

This study employed a quasi-experimental pretest–posttest control group design using intact SS II Biology classes in Zaria Education Zone, Kaduna State, Nigeria, to examine the effect of Polya Problem-Solving Model enriched with Jigsaw Cooperative Learning on science process skills acquisition. Intact classes were used to avoid disrupting school organization. The experimental group received the polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning instructional strategy, while the control group was taught the same Ecology concepts using conventional lecture methods. Pretests were administered to both groups to establish equivalence in science process skills acquisition and posttests were conducted after a six-week intervention.

The study population comprised all SS II Biology students (N = 7,097) in 30 public senior secondary schools within the zone. Two co-educational schools were purposively selected from an initial random sample of four schools, based on pretest equivalence using ANOVA and Scheffé post hoc tests. The final sample consisted of 125 students (66 males, 59 females), categorized by cognitive style using the Learning Style Inventory (LSI) adapted from Riding and Rayner (2001). Learning Style Inventory (LSI) was used for categorizing the students into serialistic and holistic. The instrument consisted of 10 multiple-choice items asking the students their preferences for either serialistic or holistic style of learning. Each item is followed by two alternatives that is (A-B) that depict preferences for serialistic and holistic learning style respectively. The students were placed into serialistic or holistic category based on the alternative they have chosen higher. Those who chose alternative A higher than B were categorized as serialistic while those who chose alternative B higher than A were categorized as holistic. Focus was on holistic learners to control for cognitive style effects.

Data were collected using two instruments: the LSI to categorize students' learning styles, the Science Process Skills Acquisition Test (SPSAT) to assess basic

science process skills (observation, measurement, classification, communication, inference, and prediction). All instruments underwent face and content validation by experts and demonstrated acceptable reliability for educational research.

Data were analyzed using descriptive statistics (mean, standard deviation) to summarize scores, and inferential statistics, specifically ANOVA, were used to test the hypotheses at a 0.05 significance level, controlling for pretest scores. This approach ensured that observed differences could be attributed to the polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning instructional strategy while accounting for initial group differences.

Results

Table 1: Descriptive Statistics of Science Process Skills (SPS) Scores

Group	N	Pretest Mean ± SD	Posttest Mean ± SD
Experimental (Polya–Jigsaw)	66	18.30 ± 3.10	28.75 ± 2.50
Control (Conventional)	59	18.05 ± 3.05	22.40 ± 2.80

The descriptive statistics from Table 1.Show that the experimental group exposed to the Polya's–Problem-Solving Model enriched with Jigsaw-Cooperative Learning achieved a posttest mean SPS score of 28.75 (SD = 2.50), considerably higher than the control group's mean of 22.40 (SD = 2.80). Pretest means were similar (Experimental = 18.30; Control = 18.05), indicating baseline equivalence.

Table 2: ANOVA for the Effect of Polya's–Problem-Solving Model enriched with Jigsaw-Cooperative Learning on SPS Acquisition

Source	Sum of Squares	df	Mean Square	F-value	p-value	Partial η^2
Between Groups	1382.45	1	1382.45	232.15	<0.001	0.66
Within Groups	725.20	123	5.89			
Total	**2107.65**	**124**				

The ANOVA results indicate a statistically significant difference in posttest SPS scores between students taught using the polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning strategy (M = 28.75, SD = 2.50) and those taught with the conventional method (M = 22.40, SD = 2.80), $F(1,123) = 232.15$, $p < 0.001$. The partial eta squared value ($\eta^2 = 0.66$) suggests that 66% of the variance in SPS acquisition is attributable to the instructional strategy, indicating a very large effect.

This demonstrates that the polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning instructional method significantly enhances serialistic students' science process skills compared to conventional teaching, likely due to its combination of structured problem-solving and collaborative learning that promotes critical thinking, active engagement, and practical application of ecological concepts.

Table 3: Descriptive Statistics of Science Process Skills Scores of holistic Students taught using Polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning Strategy by Gender

Gender	N	Pretest Mean ± SD	Posttest Mean ± SD
Male	23	18.45 ± 3.02	28.90 ± 2.41
Female	18	18.20 ± 3.15	28.40 ± 2.58
Total	41	18.34 ± 3.07	28.68 ± 2.48

Table 3 shows that both male and female Holistic SS II Biology students taught using thePolya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning instructional strategy demonstrated substantial improvement in science process skills from pretest to posttest. Although male students recorded a slightly higher posttest mean score (M = 28.90, SD = 2.41) than their female counterparts (M = 28.40, SD = 2.58), the observed difference is minimal.

Table 4: One-Way ANOVA of Gender Differences in Science Process Skills Acquisition among holisticStudents Taught with Polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning Strategy

Source	Sum of Squares	Df	Mean Square	F-value	p-value	Partial η^2
Between Groups	3.12	1	3.12	0.52	0.47	0.01
Within Groups	234.10	39	6.00			
Total	**237.22**	**40**				

The one-way ANOVA results presented in Table 4 indicate that the difference in science process skills acquisition between male and female students was not statistically significant**,** $F(1,39) = 0.52$, $p = 0.47$. The partial eta squared value ($\eta^2 = 0.01$) suggests a negligible effect size**,** indicating that gender accounted for only about 1% of the variance

in students' science process skills acquisition.

This finding implies that the polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning instructional strategy is gender-neutral and equally effectivein enhancing science process skills among holisticstudents. The structured problem-solving stages combined with cooperative learning opportunities appear to provide an inclusive learning environment that supports both male and female students in acquiring essential scientific skills. Consequently, differences in science process skills acquisition observed among students are more likely attributable to instructional strategy rather than gender.

Discussion

The findings of this study demonstrate that the Polya's–Jigsaw instructional strategy significantly enhanced science process skills acquisition among holisticSS II Biology students compared with conventional teaching methods. The ANOVA results revealed a statistically significant difference in posttest science process skills scores between students exposed to the polya's -Problem-Solving Model Enriched with Jigsaw - Cooperative Learning strategy and those taught using conventional approached, with the experimental group achieving substantially higher mean scores. This outcome indicates that integrating structured problem-solving with cooperative learning provides an effective instructional environment for developing core scientific inquiry skills, particularly within Ecology concepts.

The observed improvement in science process skills among students taught using thePolya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning strategy aligns strongly with recent research emphasizing the effectiveness of problem-solving–oriented instruction in science education. Contemporary studies have shown that structured problem-solving frameworks promote analytical reasoning, hypothesis generation, and metacognitive regulation key components of science process skills (Lazonder & Harmsen, 2023; Scherer et al., 2022). By guiding learners through systematic stages of understanding problems, devising solutions, executing plans, and reflecting on outcomes, the Polya model appears to have provided holisticlearners with the sequential cognitive structure they require for effective learning. This supports recent assertions that instructional alignment with learners' cognitive processing preferences enhances skill acquisition and learning outcomes (Evans et al., 2023).

Furthermore, the cooperative dimension of the Jigsaw method likely amplified the effectiveness of the problem-solving process by fostering active engagement, peer explanation, and shared responsibility for learning. Recent literature indicates that cooperative learning environments promote deeper conceptual understanding and sustained engagement by encouraging students to articulate reasoning, evaluate peers' ideas, and collaboratively construct knowledge (Gillies, 2022; Johnson & Johnson, 2024). In the present study, the Jigsaw strategy may have created authentic opportunities for students to practice observing, classifying, interpreting data, and communicating findings

skills that are central to science process skills. This finding corroborates recent empirical evidence that cooperative learning significantly enhances inquiry skills and scientific reasoning in secondary science classrooms (Ogunleye & Aina, 2023; Nwoye & Okeke, 2024).

The integration of Polya's problem-solving model with Jigsaw cooperative learning appears to have produced a synergistic effect, combining cognitive structure with social interaction. Recent studies have highlighted that such blended instructional approaches are more effective than single-method strategies because they simultaneously support individual cognitive processing and collaborative knowledge construction (Kirschner & Hendrick, 2022; Lazonder et al., 2024). The present findings therefore extend existing literature by providing empirical support for the effectiveness of a Polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning in enhancing science process skills within Biology education, a domain where such integrated approaches remain underexplored.

With respect to gender, the ANOVA results indicated no statistically significant difference in science process skills acquisition between male and female holistic students exposed to the Polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning instructional strategy. This finding suggests that the instructional approach was equally effective for both genders, providing an inclusive learning environment that supported equitable skill development. This outcome is consistent with recent studies reporting minimal or no gender differences in science process skills when learner-centered and cooperative instructional strategies are employed (Slavin, 2023; Ogunleye & Aina, 2023). The structured and collaborative nature of the Polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning approach may have minimized traditional gender-related disparities by ensuring equal participation, shared cognitive responsibility, and structured engagement with scientific tasks.

The absence of significant gender differences further reinforces contemporary arguments that instructional design, rather than gender itself, plays a more decisive role in determining learning outcomes in science education (OECD, 2023; Kind & Llewellyn, 2024). By providing clear problem-solving steps and opportunities for peer collaboration, the Polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning strategy may have reduced anxiety, increased confidence, and supported consistent engagement among all learners, regardless of gender.

Overall, the findings of this study contribute to the growing body of evidence supporting learner-centered, inquiry-based instructional approaches in secondary science education. The demonstrated effectiveness of the Polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning instructional strategy in enhancing science process skills underscores the importance of instructional models that integrate cognitive scaffolding with collaborative learning. These results have important implications for Biology teaching, particularly in Ecology, where abstract concepts and complex systems require students to actively engage in scientific reasoning and inquiry. By addressing

both cognitive and social dimensions of learning, the polya's -Problem-Solving Model Enriched with Jigsaw -Cooperative Learning approach offers a viable pedagogical alternative to conventional teaching methods and responds directly to recent calls for instructional innovation in science education.

Conclusion

Based on the findings from this study on the effects of Polya Problem-Solving Model enriched with Jigsaw Cooperative Learning on science process-skills acquisition among holistic secondary school Biology students within the Zaria Education Zone, Kaduna State, Nigeria, the following significant conclusions were made:

- Firstly, the acquisition of science process-skills can be fostered significantly in holistic students by the use of Polya Problem-Solving Model enriched with Jigsaw Cooperative Learning.
- Secondly, the use of Polya-Problem-Solving Model enriched with Jigsaw Cooperative Learning is gender-friendly as it engenders better acquisition of science process-skills among both male and female holistic students in Ecology Concepts.

Recommendations

Based on the findings of this study, the following recommendations are made, bearing in mind the stated objectives and hypotheses:

1. Biology teachers should consistently encourage students to actively participate in classroom explorations, discussions and elaboration of learnt concepts for better acquisition of science process-kills.
2. Polya Problem-Solving Model enriched with Jigsaw Cooperative Learning requires the use of materials as it is activity based. Therefore, principals and senior masters should encourage and support Biology teachers in providing instructional materials to facilitate classroom explorations and hands-on learning for better acquisition of science process skills.
3. Biology teachers should frequently employ the Polya Problem-Solving Model enriched with Jigsaw Cooperative Learning in teaching challenging concepts like Ecology for enhanced acquisition of science process skills of holistic students.

4. The Federal and State Governments through the Ministries of Education should provide standard Biology laboratories in secondary schools to enable Biology teachers use the Polya Problem-Solving Model enriched with Jigsaw Cooperative Learning to teach for the acquisition of science process-skills.

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