Problem-Based Learning and Inquiry Method on Performance in Ecology Concepts among Secondary School Biology Students

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Abstract
The study investigated the effect of instructional strategy (Problem-Based Learning, Inquiry Method and Lecture Method) on the performance in Ecology concepts among secondary school Biology students in Ikwerre Local Government Area, Rivers State. The study adopted the quasi-experimental design. From the population of 3,217 senior secondary school one Biology students, 73 males and 70 females totaling 143 students were selected from three (3) schools in the study area, using purposive sampling. Two (2) research questions were raised and answered. Two (2) hypotheses were formulated and tested at 0.05 level of significance. The research instruments tagged "Basic Ecology Performance Test" was developed by the researcher and was deployed for the study. When subjected to Kuder-Richardson 21 formular, the Basic Ecology Performance Test scored a reliability of 0.81. The research questions raised were answered using mean and standard deviation, and the hypotheses formulated were tested using Analysis of Covariance, while Post-Hoc analysis was done with Bonferroni. The findings of the study revealed that the performance was highest among students taught using Problem-Based Learning, followed by those taught using Inquiry Method, while those taught using Lecture Method had the least performance. This study will be of immense benefit to Science teachers for the reason that it will guide them on the best method to employ in the teaching of scientific concepts in Ecology, thereby providing insights into improving Biology education outcomes in Ikwerre Local Government Area, Rivers State.

Keywords: Problem-based learning, Inquiry method, Performance, Gender, Ecology.

Introduction

Performance as used in the field of Education, could be defined as follows: Performance as Academic Achievement: Performance refers to the level of academic achievement demonstrated by students on various assessments." (Kuhn & Hmelo-Silver, 2020). Performance as Competence Demonstration: "Performance is the demonstration of competence or mastery of specific skills, knowledge, or attitudes." (Baartman, 2022,). Performance as Learning Outcomes: "Performance is the measurement of learning outcomes, including knowledge, skills, and attitudes acquired by students." (Boud & Soliman, 2020). Performance as Cognitive Ability: "Performance is the manifestation of cognitive abilities, such as critical thinking, problem-solving, and reasoning." (Pellegrino & Hilton, 2021). Performance as Behavioural Demonstration: "Performance is the demonstration of behaviours, such as communication, teamwork, and time management." (Durlak et al., 2022). Performance as Standard-Based Achievement: "Performance is the degree to which students meet established standards or benchmarks." (Popham, 2020). Performance as Authentic Assessment: "Performance is the demonstration of learning through authentic, real-world tasks and applications." (Wiggins & McTighe, 2020). Performance as Student Engagement: "Performance is the measure of student engagement, motivation, and participation in learning activities." (Fredricks et al., 2023). Performance as Long-Term Retention: "Performance is the measure of long-term retention and recall of learned material." (Cepeda et al., 2020). Performance as Career Readiness: "Performance is the demonstration of skills, knowledge, and attitudes necessary for success in post-secondary education and the workforce." (National Academy of Sciences, 2023).

Instructional strategies refer to a comprehensive scheme of activities directed at realising educational objectives and also defending against the militating factors to realising such educational objectives. (Nwanekezi & Ugonwa, 2021).

Problem-Based Learning (PBL) is a student-centred educational strategy that involves students working in groups to explore real-world problems or scenarios, fostering critical thinking, creativity, and problem-solving skills (Salvin-Baden & Major, 2022). Problem-Based Learning can improve performance by developing critical thinking and problem-solving skills, enhancing collaboration and teamwork, encouraging active learning and engagement, improving transfer of learning to new situations and developing research and information literacy skills.

Inquiry method is a student-centred educational strategy that encourages active exploration, investigation, and discovery of concepts and principles through open-ended questions and real-world scenarios. (Lunn Brownlee, 2022). Its key characteristics includes student-led investigation; open-ended questions or problems; active exploration and discovery; emphasis on process over product and collaborative learning. Inquiry method can improve performance by developing critical thinking and analytical skills, enhancing scientific literacy and numeracy, fostering creativity and problem-solving, improving research and information literacy and by encouraging active learning and engagement.

In the context of education and organizational settings, understanding the concepts of gender, male, and female is crucial for promoting performance. Gender refers to the socially constructed roles, behaviours, and expectations associated with being male or female (World Health Organization, 2024). Traditionally, male refers to individuals assigned male at birth, typically characterized by biological and physiological characteristics such as XY chromosomes and testosterone dominance (Kessler & McKenna, 2022). Research highlights the importance of considering gender dynamics in promoting performance and retention. Disparity due to gender can be addressed by creating inclusive environments that value diversity and which can address gender biases and can enhance performance among all individuals, particularly underrepresented groups (Eagan et al., 2020); by incorporating gender-sensitive teaching methods and materials which can improve academic outcomes and engagement (Bourn, 2022); by challenging traditional gender stereotypes and promoting gender equity which can foster positive attitudes towards learning and increase retention rates (UNESCO, 2024).

Mehboob et al. (2021), worked on inquiry-based method on academic achievement of Biology students at secondary level in Hazara division in Pakistan, using a pre-test, post-test equivalent group design. The study involved one hundred and twenty (120) science students. The study revealed that the experimental group significantly performed better than the control group. Bibi et al (2024), investigated whether inquiry-based teaching might improve Biology pupil achievement compared to lecture-based methods. The study was conducted using eighty (80) students from government secondary schools from the district of Mardan, in Pakistan. An experimental design—a Pre-test, Post-test equivalent group design was used. These results support the expanded use of inquiry-based teaching methodologies in secondary education to improve learning outcomes by showing that they improve Biology academic achievement across student demographics.

Akinwumi and Falemu (2017), investigated the effects of problem-solving teaching approach on students' academic performance in Biology in senior secondary school. The design for this study was a two group Pretest-Posttest Quasi-Experimental. The population for the study was all the senior secondary class two (SS2) Biology students in Ikere Local Government Area of Ekiti State, Nigeria. The sample comprised of sixty (60) senior secondary class two students selected from two senior secondary schools in the Ikere Local Government Area of Ekiti State. The findings showed that no significant difference existed in the academic performance between male and female students in the experimental group.

Statement of the Problem
Although Biology is a major Science subject at the senior secondary school in Nigeria, students' performance at the West African School Certificate Examination (WASCE) has been reported to be poor. Zita & Winifred as cited in Usman et al. (2023), stated that the West African Examination Council reported that Biology achievement of students in Nigeria was low in terms of credit level which qualifies students for admission into institutions of higher learning. Despite the potential benefits of Problem-Based Learning and Inquiry methods, their adoption in Nigerian secondary schools remains limited. Ikwerre L.G.A, Rivers State, is no exception. This has led to this

study on the effect of Problem-Based Learning and Inquiry strategies on secondary school Biology students' performance of Ecology concepts in Ikwerre Local Government Area (L.G.A), Rivers State.

Aim and Objectives of the Study
The study investigated the effect of instructional strategy (problem-based learning, inquiry method and lecture method) on the performance in Ecology concepts among secondary school Biology students in Ikwerre Local Government Area, Rivers State. In specific terms, the study sought to:
1. investigate the effect of instructional strategy (problem-based learning, inquiry method and lecture method) on students' performance in Ecology;
2. ascertain the influence of gender on students' performance in Ecology;

Research Questions
The following research questions were raised to guide this study:
1. What is the mean performance difference in Ecology among students taught using problem-based learning, those taught using inquiry method and those taught using lecture method?
2. What is the mean difference in performance in Ecology between male and female students?

Hypotheses
The following null hypotheses were formulated and were tested at 0.05 level of significance in the study.
1. There is no significant difference in performance among students taught Ecology using problem-based learning, those taught using inquiry method and those taught using lecture method.
2. There is no significant difference in performance between male and female students taught Ecology.

Materials and Methods
The study adopted the quasi-experimental design. The population of the study consisted of all the students in senor secondary school one (SSS 1) in Ikwerre Local Government Area of Rivers State. As at the time of the study, there were 3,217 senior secondary one (SSS 1) Biology students in all the seventeen (17) public secondary schools in Ikwerre Local Government Area of Rivers State. Based on the certain criteria, 3 secondary schools were randomly selected for the study. The schools and participants were further distributed into two experimental groups and a control group. In each school, an intact class was selected randomly for the study. 73 males and 70 females totaling 143 students were used for this study. The research instrument tagged "Basic Ecology Performance Test" (BEPT) was developed by the researcher and was employed for the study. The Basic Ecology Performance Test (BEPT) was validated based on face, content and construct validity. The Basic Ecology Performance Test (BEPT) was trial-tested with 30 Senior Secondary School one (SSS 1) Biology students. Their responses were graded and their scores were subjected to Kuder-Richardson 21 formula to obtain a reliability coefficient of 0.81. Two research questions and two hypotheses guided the study. Data collected were analysed using descriptive statistics of mean, standard deviation and Analysis of Covariance (ANCOVA). The hypotheses were tested at 0.05 level of significance.

Results
Research Question 1: What is the mean performance difference in Ecology among students taught using problem-based learning, those taught using inquiry method and those taught using lecture method?

Table 1: Mean and Standard Deviation of Students' Performance Classified by Instructional Strategy.

Instructional Strategy		Pretest	Posttest	Mean Difference
Problem Based Learning	Mean	15.44	28.22	12.78
	N	55	55	
	Std. Deviation	3.915	5.290	
Inquiry Method	Mean	14.45	20.40	5.95
	N	53	53	
	Std. Deviation	5.628	6.292	
Lecture Method	Mean	13.37	18.06	4.69
	N	35	35	
	Std. Deviation	4.180	4.589	

Table 1 shows the mean and standard deviation of students' performance in Ecology using Problem-Based Learning, Inquiry Method and Lecture Method. The results show that the students irrespective of the instructional strategy used showed appreciable performance. It was indicated that students taught Basic Ecology Concepts using Problem-Based Learning had mean difference of 12.78; those taught using Inquiry Method had a mean difference of 5.95; while those taught with Lecture method had a mean difference of 4.69. The findings of the study therefore revealed that the performance was highest in students taught using Problem-Based Learning, followed by those taught using Inquiry Method, while those taught using Lecture Method had the least performance.

Research Question 2: What is the mean difference in performance in Ecology between male and female students?

Table 2: Mean and Standard Deviation of Students' Performance Classified by Gender.

Gender		Pretest	Posttest	Mean Difference
Female	Mean	14.06	22.23	8.17
	N	70	70	
	Std. Deviation	4.678	7.337	
Male	Mean	15.05	23.41	8.36
	N	73	73	
	Std. Deviation	4.737	6.698	

Table 2 shows the mean and standard deviation of students' performance in Ecology with respect to gender. It indicated that female students taught Basic Ecology Concepts had mean difference of 8.17, while male students had mean difference of 8.36. The finding of the study therefore revealed that the students irrespective of the gender, showed appreciable performance.

Hypothesis 1: There is no significant difference in performance among students taught Ecology using problem-based learning, those taught using inquiry method and those taught using lecture method.

Table 3: Summary of ANCOVA of Students' Performance Classified by Instructional Strategy Using Pre-test Scores as Covariate.

Dependent Variable: Post-test scores on application

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4411.649a	3	1470.550	79.156	0.000	0.631
Intercept	1755.927	1	1755.927	94.517	0.000	0.405
Pretest	1703.624	1	1703.624	91.702	0.000	0.397
Instructional _Strategy	**2004.324**	**2**	**1002.162**	**53.944**	**0.000**	**0.437**
Error	2582.323	139	18.578			
Total	81541.000	143				
Corrected Total	6993.972	142				

a. R Squared = .631 (Adjusted R Squared = .623)

Table 3 shows that $F_{2,139} = 53.944, p = 0.00 (p < 0.05)$, therefore the null hypothesis is rejected. This indicates that there is significant effect of instructional strategy on students' performance on Ecology. A partial eta-squared value of 0.437 for instructional strategy indicates a very large effect of instructional strategy on students' performance on Ecology. Students taught Ecology using Problem-Based Learning, Inquiry Method and Lecture Method improved their performance. In order to know the direction of the significance difference, a Post Hoc analysis is done using Bonferroni

Table 4: Post Hoc Analysis of Students' Performance Classified by Instructional Strategy Using Pre-test as a Covariate.

(I) Instructional _Strategy	(J) Instructional _Strategy	Mean Difference (I–J)	Std. Error	Sig.b	95% Confidence Interval for Differenceb Lower Bound	Upper Bound
Problem Based Learning	**Inquiry Method**	7.089*	0.833	0.000	5.070	9.108
	Lecture Method	8.623*	0.946	0.000	6.331	10.914
Inquiry Method	Problem Based Learning	-7.089*	0.833	0.000	-9.108	-5.070
	Lecture Method	1.533	0.943	0.318	-0.751	3.817
Lecture Method	Problem Based Learning	-8.623*	0.946	0.000	-10.914	-6.331
	Inquiry Method	-1.533	0.943	0.318	-3.817	0.751

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.
Table 4 shows that Problem-Based Learning has the highest significant mean difference (I - J) when compared to Inquiry Method (7.089) and Lecture Method (8.623). This indicates that students taught Ecology using Problem-Based Learning, showed the highest gain in performance.

Hypothesis 2: There is no significant difference in performance between male and female students taught Ecology.

Table 5: Summary of ANCOVA of Students' Performance Classified by Gender Using Pre-test Scores as Covariate.

Dependent Variable: Post-test scores on application

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2410.839[a]	2	1205.419	36.822	0.000	0.345
Intercept	1382.770	1	1382.770	42.239	0.000	0.232
Pretest	2360.881	1	2360.881	72.117	0.000	0.340
Gender	**3.513**	**1**	**3.513**	**0.107**	**0.744**	**0.001**
Error	4583.133	140	32.737			
Total	81541.000	143				
Corrected Total	6993.972	142				

a. R Squared = .345 (Adjusted R Squared = .335)

Table 5 shows that $F_{1,140} = 0.107, p = 0.744(p > 0.05)$, therefore the null hypothesis is retained. A partial eta-squared value of 0.001 for instructional strategy indicates a very small effect of instructional strategy on students' performance on Ecology. This indicates that there is no significant effect of gender on students' performance on Ecology.

Discussion

The effect of instructional strategy (problem-based learning, inquiry method and lecture method) on students' performance in Ecology

The results show that the students irrespective of the instructional strategy used showed appreciable performance. The findings of the study revealed that the performance was highest in students taught using Problem-Based Learning, followed by those taught using Inquiry Method, while those taught using Lecture Method had the least performance. The findings of the present work agree with the findings of Fatima and Mohamed (2017), who studied the effect of guided inquiry teaching method on senior secondary school Biology students' academic achievement and retention in Yola education zone, Adamawa State, Nigeria. Quasi experimental research designed involving pre-test, post-test control group was employed. The population of the study was all the senior secondary school year two students (SSII) in Yola education zone. Stratified random sampling technique was used to select 119 Biology students. The findings show that students taught with guided inquiry method have a significantly higher academic achievement than those taught with lecture method while those taught with lecture method retained Biology concepts more than those taught with guided inquiry method. The study also found that there is significant effect of instructional strategy on students' performance on Ecology. Students taught Ecology using Problem-Based Learning, Inquiry Method and Lecture Method would improve in performance. In order to know the direction of the significance difference, a Post Hoc analysis was done using Bonferroni. The Post-Hoc showed that Problem-Based Learning has the highest significant mean difference (I - J) when compared to Inquiry Method and Lecture Method. This indicates that students taught Ecology using Problem-Based Learning showed the highest gain in performance.

The influence of gender on students' performance in Ecology

This study also revealed that female students taught Basic Ecology Concepts had appreciation in mean performance difference. Male students also had an appreciation in mean difference. The finding of the study therefore revealed that the students irrespective of the gender, showed appreciable performance. This study also indicates that there was no significant effect of gender on students' performance in Ecology. The findings of this research agree with the findings of Akinwumi and Falemu (2017), who investigated the effects of problem-solving teaching approach on students' academic performance in Biology in senior secondary school. The design for this study was a two group Pretest-Posttest Quasi-Experimental. The population for the study was all the senior secondary class two (SS2) Biology students in Ikere Local Government Area of Ekiti State, Nigeria. The sample comprised of sixty (60) senior secondary class two students selected from two senior secondary schools in the Ikere Local Government Area of Ekiti State. The findings showed that no significant difference existed in the academic performance between male and female students in the experimental group.

Conclusion

The study was able to establish the effect of Problem-Based Learning and Inquiry Method on the performance in Ecology concepts in secondary school students in Ikwerre L.G.A. Rivers State. This research shows that both PBL and IM can enhance performance, but with varying degrees of effectiveness. In Performance, PBL has been showed to improve critical thinking and problem-solving skills more significantly than IM. In conclusion, both Problem-Based Learning and Inquiry Method are effective instructional strategies for promoting performance in Ecology concepts among senior secondary school students.

Recommendations

1. Based on the results that Problem-Based Learning showed the highest gain in performance in Ecology concept, it is recommended that science teachers should employ the Problem-Based Learning as much as possible in the teaching of scientific concepts in Ecology. School administrators to should channel resources towards encouraging Problem-Based Learning. Organisations and institution should develop teacher-training programme that will inculcate the Problem-Based Learning so as to equip the trainee teacher with effective teaching capabilities.
2. Based on the results that gender does not have any significant effect on performance in Ecology, it is recommended that there should be no preferential treatment or discrimination based on gender in performance test administration and evaluation by teachers, school administration, organisations and institutions.

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