

**Effects of Team and Project-based Learning Strategies on Senior Secondary School
Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria**

Rebecca Iyabo OGUNRINDE

LCU/PG/005618

**Being a MSc (Ed) Thesis Submitted to the Department of Science Education, Faculty of
Education, Lead City University, Ibadan, Oyo State, Nigeria**

**In Partial Fulfilment of the Requirements for the Award of Master of Science Education
Degree (MSc (Ed)) in Biology Education**

2025

Certification

This is to certify that Rebecca Iyabo OGUNRINDE with Matriculation Number LCU/PG/005618 carried out this research titled “Effects of Team and Project-based Learning Strategies on Senior Secondary School Students’ Achievement in Ecology in the Abeokuta Metropolis, Nigeria” in the Department of Science Education, Faculty of Education, Lead City University, Ibadan, Oyo State, Nigeria, for the award of Master of Science Education Degree MSc(Ed) in Biology Education and that this has not been previously submitted to any Institution for the award of any Degree or Certificate.

Dr. C. O. Sam-Kayode
Promoter

Date

Prof. P. O. Yara
Head of Department

Date

Dedication

This research is dedicated to God Almighty for the grace given to me during the course of this study, may His name be praise for ever.

Lead City University Ibadan DO NOT COPY

Acknowledgment

With the heart full of appreciation, I acknowledge this great citadel of learning, Lead City University, Ibadan, Oyo State, Nigeria for the opportunity to be imparted and to conduct this research. I equally appreciate Abeokuta Grammar School; Rev Kuti Memorial Grammar School; and Nar-waar-Deen Grammar School for the opportunity to carry out this research in their schools.

My sincere appreciation goes to my supervisor, who also doubled as the Postgraduate Coordinator in the Department of Science Education, Dr. Christianah O. Sam- Kayode. who took her time to correct and supervised this work to make it a success; I appreciate the effort of the Provost, Postgraduate College, Prof. Afolakemi O. Oredein; the Dean, Faculty of Education, Prof. D.A. Odeleye; the Head of Department of Science Education, Prof. P. O. Yara; Prof. B. Adebo; Prof. S. E Ileuma; Asso. Prof. U.E Akuche, Asso. Prof. Toyin Oyedeggi; Asso. Prof. M.D. Oyetade; Asso. Prof. O.S Pitan; Dr. Bamidele S. Omoyajowo; Dr. Olabisi Killian; Dr. 'Seyi David; Dr. Deborah Ayeni; Dr. Omobola Gambo; Dr. Hafsat Abdulsemihi; Dr. Azeez A. Waheed; Dr. Moyinoluwa Owojori; Miss Omenihu G. Uduali; Miss Adedolapo Awoniyi; Mr. Feranmi E. Adejuwon; and Mrs, Ebunoluwa Adams.

I am sincerely grateful to my husband, Mr. J A Ogunrinde for his unmeasurable support and contributions to success of this research. I appreciate my children, Toluwanimi; Ayanfeoluwa; Emmanuel; and Emmanuella. I am thankful to all the staff at the Teaching Service Commission Office, Abeokuta, Ogun State; Dr. J.O. Onipede; Mr. I Mohammed; Mr. A.Gideon; Mrs. A.A. Shosanya; Mr. R. Tunde; Pastor and Pastor (Mrs.)

D.A. Akaraiwe; Mrs S..Hamzat; Mrs D. Ibiyemi and Mr. H. Muazu. Your contributions have led to this success. God bless you all.

Even though the institutions and individuals previously mentioned provided assistance with this research, I alone am responsible for any mistakes that may have been committed.

Lead City University Ibadan DO NOT COPY

Abstract

Chief Examiner's reports of WAEC highlight persistent challenges, particularly in Ecology, where students struggle with critical thinking, analytical reasoning, and real-world application of biological concepts. This study determined the Effects of Team and Project-based learning strategies on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria. Four hypotheses were formulated and tested at 0.05 level of significance. The pretest–posttest control group quasi–experimental design was adopted. The study population comprises 3,680 SS II students (1,706 male and 1,974 female students); from which, a total of 91 participants (44 male and 47 female students) from the three randomly selected schools participated in this study. Ecology Achievement Test (EAT) (KR-20 = 0.76) and Instructional Guides for Teaching and Learning Ecology were used as instruments for data collection. Analysis of Covariance (ANCOVA) was used for data analysis. There was a significant main effect of Team–based learning strategy on senior secondary school students' achievement in Ecology ($F_{(1; 55)} = 160.770$, $p < 0.05$, partial $\eta^2 = 0.745$). There was significant main effect of Project-based learning strategy on senior secondary school students' achievement in Ecology ($F_{(1; 57)} = 79.050$, $p < 0.05$, partial $\eta^2 = 0.581$). There was no significant main effect of gender on senior secondary school students' achievement in Ecology ($F_{(1; 88)} = 0.002$, $p > 0.05$, partial $\eta^2 = 0.000$). There was significant interaction effect of Team–based learning strategy, Project-based learning strategy and gender on senior secondary school students' achievement in Ecology ($F_{(5; 84)} = 40.191$, $p < 0.05$, partial $\eta^2 = 0.705$). Based on the findings, the study concludes that Team-based and Project-based Strategies enhanced students' achievement. The study recommends the adoption of these innovative strategies in teaching Ecology to promote better academic outcomes among senior secondary school students regardless of gender differences.

Keywords: Academic achievement in Ecology, Team–based learning strategy, Project-based learning strategy, Traditional teaching strategy

Word Count: 297

Table of Contents

Content	Page
Title Page	i
Certification	ii
Dedication	iii
Acknowledgments	iv
Abstract	vi
Table of Contents	vii
List of Tables	xi
List of Figure	xiv
List of Acronyms	xv
Chapter One: Introduction	
1.1 Background to the Study	1
1.2 Statement of the Problem	9
1.3 Aim and Objectives of the Study	10
1.4 Hypotheses	11
1.5 Significance of the study	11
1.6 Scope of the Study	13
1.7 Limitation of the Study	14
1.7 Operational Definition of Terms	14
Endnotes	16
Chapter Two: Literature Review	
2.1 Conceptual Review	20

2.1.1	Academic Achievement	21
2.1.2	Biology	24
2.1.3	Ecology	30
2.1.4	Teaching Strategies	36
2.1.4.1	Team-based Learning Strategy	40
2.1.4.2	Project-based Learning Strategy	43
2.1.4.3	Traditional Teaching Strategy	47
2.1.5	Gender	54
2.2	Theoretical Framework	60
2.2.1	Constructivist Learning Theory	60
2.3	Review of Empirical Studies	78
2.3.1	Team-based Learning Strategy and Academic Achievement in Ecology	78
2.3.2	Project-based Learning Strategy and Academic Achievement in Ecology	84
2.3.2	Gender and Academic Achievement in Ecology	92
2.4	Conceptual Model	100
2.5	Summary of Literature Reviewed	101
	Endnotes	103

Chapter Three: Methodology

3.1	Research Design	113
3.2	Population of the Study	114
3.3	Sample and Sampling Techniques	115
3.4	Description of the Research Instruments	118
3.4.1	Ecology Achievement Test (EAT)	118
3.4.2	Instructional Guide for Teaching and Learning Ecology based on	

Team-based Learning Strategy	119
3.4.3 Instructional Guide for Teaching and Learning Ecology based on Project-based Learning Strategy	120
3.4.4 Instructional Guide for Teaching and Learning Ecology based on Traditional Teaching Strategy	120
3.5 Validity of the Research Instruments	121
3.6 Reliability of the Research Instrument	121
3.7 Methods of Data Collection	122
3.8 Methods of Data Analysis	123
3.9 Ethical Approval	123
Endnotes	124
Chapter Four: Results and Discussion of Findings	
4.1 Demographic Data Analysis	125
4.2 Presentation of Data	125
4.2.1 Hypotheses	125
4.3 Discussion of Findings	134
Endnotes	142
Chapter Five: Conclusion	
5.1 Summary of Findings	144
5.2 Conclusion	145
5.3 Recommendations	145
5.4 Contribution to Knowledge	146
5.4.1 Implication for Researchers	146
5.4.2 Implication for Practitioners	146
5.5 Suggested Area for Further Research	147

Bibliography	148
Appendix I	160
Appendix II	163
Appendix III	164
Appendix IV	167
Appendix V	170
Bio-data	173
The University Compliance Certification	176

List of Tables

Table	Title	Page
3.1	Research Schema	113
3.2	Schematic Representation of the 3×2 Factorial Matrix	114
3.3	Study Population	115
3.4	Random Sampling for selected Public Senior Secondary Schools	117
3.5	Table of Specification	119
4.1.0	Team-based Learning Strategy, Project-based Learning Strategy and Traditional Teaching Strategy	125
4.1.1	Tests of Between-Subjects Effects of Team-based Learning Strategy on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria	126
4.1.2	Estimated Marginal Means of Team-based Learning and Traditional Teaching Strategies on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria	127

4.2.1	Tests of Between-Subjects Effects of Project-based Learning Strategy on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria	128
4.2.2	Estimated Marginal Means of Project-based Learning and Traditional Teaching Strategies on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria	129
4.3.1	Tests of Between-Subjects Effects of Gender on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria	130
4.3.2	Estimated Marginal Means of Gender on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria	131
4.4.1	Tests of Between-Subjects Effects of Team-based Learning Strategy, Project-based Learning Strategy and Gender on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria	132
4.4.2	Estimated Marginal Means of Team-based Learning Strategy, Project-based Learning Strategy and Gender on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria	133

List of Figure

Figure	Title	Page
2.1	Conceptual Model of Team-based and Project-based Learning Strategies on Academic Achievement in Ecology	100

Lead City University Ibadan DO NOT COPY

List of Acronyms

Abbreviation	Meaning
DNA	Deoxyribonucleic Acid
STEM	Science, Technology, Engineering and Mathematics
PBL	Problem-Based Learning
SS2	Senior Secondary Two
KR – 20	Kuder – Richardson
ANCOVA	Analysis of Covariance
WASSCE	West African Senior School Certificate Examination
WAEC	West African Examination Council
IBL	Inquiry-based Learning
TBL	Team-based Learning
STEM	Science, Technology, Engineering, and Mathematics
iRAT	individual Readiness Assurance Test
ZPD	Zone of Proximal Development
LMS	Learning Management System
BPT	Biology Performance Test
ANCOVA	Analysis of Covariance
BATS	Biology Achievement Test for Students
HOTS	Higher-Order Thinking Skills
BAT	Biology Achievement Test
SS2	Senior Secondary Two
EAT	Ecology Achievement Test
STEM-PBL	STEM Problem-based Learning
CLM	Conventional Lecture Method

FTIS	Field Trip Teaching Strategy
STEAM	Science, Technology, Engineering, Arts, and Mathematics
CSCL	Computer-Supported Collaborative Learning
CMA	Comprehensive Meta-Analysis
CSCL	Computer-Supported Collaborative Learning
SS1	Senior Secondary One
tRAT	team Readiness Assurance Test
LGAs	Local Government Areas
SSSC	Senior Secondary School Certificate

Chapter One

Introduction

1.1 Background to the Study

Biology holds a central place in the senior secondary school curriculum, serving as a gateway to understanding the structure, function, and interactions of living organisms within their environment. In one of its key areas, Ecology, provides students with essential insights into the relationships between organisms and their habitats and the importance of environmental sustainability¹. Despite its significance, the teaching of Ecology in many Nigerian schools, particularly in the Abeokuta Metropolis, is often delivered through conventional lecture methods that do not actively engage learners or promote deep conceptual understanding. This situation has raised concerns about how best to improve student participation and comprehension in Biology classrooms. As such, there is a growing interest in the use of innovative instructional strategies, such as team-based and project-based learning, which emphasize collaboration, inquiry and real-life application of knowledge. These strategies are believed to not only enhance students' interest in Ecology but also foster critical thinking and retention of scientific concepts. It is against this backdrop that this study investigates the effects of these strategies in improving students' understanding of Ecology, using their achievement as a measure of learning outcomes.

Achievement is a critical measure of student success, reflecting their mastery of subject material and preparedness for higher education and employment. In Nigeria, the West African Senior School Certificate Examination (WASSCE) serves as the primary benchmark for evaluating students' academic performance, in many subjects including Biology. Students' performance in the WAEC Biology examination in Ogun State has

experienced fluctuations but has generally trended upward in terms of credit-level passes (C6 and above) over the years. From 2016 to 2019, pass rates hovered between 50% and 55%, with slight improvements linked to teacher training initiatives and curriculum enhancements. However, in 2020, scores dropped significantly to 51.4%, primarily due to the disruptions caused by the COVID-19 pandemic, which severely disrupted academic activities across the country^{1,2}.

Over the past five years, the performance of students in Ogun State in the WAEC Biology examination has shown a gradual upward trend, despite previous fluctuations in earlier years. The percentage of candidates who obtained at credit level (C6 and above) during this period was: 51.4% (2020), 58.2% (2021), 58.9% (2022), 61.4% (2023), and 63.3% (2024). The notable decline in 2020, likely due to the disruptions caused by the COVID-19 pandemic, followed by a steady improvement in subsequent years. This rise in performance can be attributed to stronger educational interventions, increased emphasis on practical-based learning, and a more stable academic calendar. By 2024, the pass rates had reached the highest level, indicating progress in science education within the state^{2,3,4}. In 2022, the WAEC Chief Examiners' report revealed that students lack a comprehensive understanding of basic biological principles and struggle with applying theoretical knowledge practically, especially in topics like Ecology that require analytical thinking and problem-solving skills^{2,3}.

Ecology, a vital subset of Biology, involves studying the relationships between organisms and their environments. This field is increasingly important in the Nigerian educational system, given the country's environmental challenges, such as deforestation, pollution, and loss of biodiversity. Teaching Ecology equips students with the knowledge

and skills to address these environmental issues through conservation and sustainability practices. However, students often find Ecology concepts challenging due to the abstract nature of ecological relationships and the lack of practical, hands-on learning experiences in schools⁵. To overcome these challenges, teaching methods that emphasize active involvement, practical applications, and critical thinking are essential⁶.

Over the years, educators and researchers have explored different strategies to improve academic achievement in Ecology. Traditional methods, such as lecture-based teaching, remain widely used but often fail to engage students actively, leading to passive learning and limited retention⁷. To address these limitations, various learner-centered strategies have been introduced. One of these strategies is Inquiry-based Learning (IBL), which encourages students to ask questions, conduct experiments, and draw conclusion based on their findings⁸. Although Inquiry-based Learning has proven effective in promoting critical thinking, its implementation is hindered by limited resources and a lack of adequate training among teachers. Additionally, cooperative learning, which promotes collaboration among students, has shown promise in enhancing learning outcomes, but its impact in large classrooms often faces challenges⁹. Studies have called for more innovative, interactive approaches like Team-based Learning (TBL) and Project-based Learning (PBL) that align better with the dynamic, practical nature of Ecology¹⁰.

Team-based Learning (TBL) is an instructional strategy that emphasizes teamwork and structured collaboration among students. Through team-based learning, students work in small groups to engage in problem-solving, fostering both independent and collective learning¹¹. In science education, team-based learning has gained attention

for its ability to improve comprehension and retention by promoting active engagement with course material¹². The collaborative structure of team-based learning aligns well with the teaching of Ecology, as it encourages students to approach ecological concepts from multiple perspectives, enhancing their understanding and ability to apply knowledge to real-world environmental issues¹³. Studies have shown that team-based learning can significantly enhance students' critical thinking and teamwork skills, particularly in subjects that require the integration of complex information, such as Ecology¹⁴. Furthermore, team-based learning has been linked to improved academic outcomes, as students often retain information more effectively when they actively participate in group discussions and problem-solving activities¹⁵.

Project-based Learning (PBL) is a learner-centered strategy that involves students working on projects over an extended period to explore and apply subject matter¹⁶. Project-based learning encourages students to engage with real-life issues, making learning more relevant and fostering critical thinking, creativity, and collaboration. In the context of Ecology, Project-based Learning can be particularly effective as it enables students to address environmental topics directly by conducting field research, analyzing ecological data, and developing conservation strategies¹⁷.

Project-based learning has been widely recognized for its positive impact on students' motivation, engagement, and academic performance, especially in subjects that require hands-on, experiential learning¹⁸. However, while project-based learning holds great promise, its implementation in Nigerian schools is often constrained by limited resources, large class sizes, and a lack of adequate training for teachers on this strategy¹⁹.

The cognitive benefits of project-based learning have been well-documented, with studies showing that it enhances students' problem-solving and research skills. In project-based Learning, students are encouraged to investigate real-world problems and devise solutions, which align with the analytical and Inquiry-based nature of Ecology. This strategy not only improves content knowledge but also equips students with skills that are essential in higher education and the workplace²⁰. In Nigerian schools, where resources are often limited, implementing Project-based Learning could allow students to utilize locally available materials, making the learning experience more relevant to their immediate environment²¹.

Studies have demonstrated that collaborative learning environments can positively impact academic achievement by promoting critical thinking, communication, and interpersonal skills. In team-based learning, the emphasis on group accountability and peer support can motivate students to stay engaged and develop a deeper understanding of the subject matter. Research shows that team-based learning helps students to think more critically about Biology topics by encouraging them to share ideas and perspectives²². Project-based learning, on the other hand, allows students to take ownership of their learning by completing projects that require applying theoretical knowledge in practical contexts, which could be especially beneficial for topics like Ecology²³.

Research also highlights the motivational impact of collaborative learning on students. Both team-based learning and project-based learning provide a sense of autonomy and purpose, which can lead to increased motivation and engagement. In a study on Biology students' attitudes towards learning, it was found that students who

participated in team-based learning and project-based learning were more motivated to learn and demonstrated a stronger commitment to understanding the material²⁴. This is particularly significant for Ecology, as students who are motivated are more likely to appreciate the relevance of ecological issues in their daily lives.

Furthermore, the implementation of team-based learning and project-based learning in Nigerian schools could enhance students' understanding of the interconnectedness of ecological systems, an understanding crucial for addressing local environmental challenges. Given Nigeria's diverse ecosystems and the ecological issues they face, equipping students with an in-depth understanding of Ecology is essential for fostering a generation that value and protects the environment. This underscores the relevance of this study, as it seeks to explore how team-based learning and project-based learning can enhance academic achievement in Ecology²⁵.

Despite the potential benefits of team-based learning and project-based learning, there are challenges in implementing these strategies in Nigerian schools, such as large class sizes, limited resources, and insufficient teacher training. Many teachers are not familiar with these strategies, and adapting the curriculum to support team-based and project-based activities requires substantial changes in instructional planning²⁶. Nevertheless, studies indicate that when effectively implemented, these strategies can be transformative, providing students with a more engaging and enriching learning experience.

Gender disparities in education remain a persistent issue globally, and Nigeria is no exception. In the field of science education, female students often face challenges that limit their academic performance, including societal expectations, reduced access to

resources, and a lack of encouragement for pursuing Science, Technology, Engineering, and Mathematics (STEM) fields²⁷. These disparities are particularly evident in rural and underserved areas, where cultural beliefs and socioeconomic factors further exacerbate the gender gap in academic achievement²⁸.

Gender differences in academic achievement, especially in science subjects, continue to be a subject of concern in Nigeria and worldwide. Historically, male students have outperformed female students in science and technology subjects, which has led to gender imbalances in Science, Technology, Engineering, and Mathematics (STEM) fields²⁹. Socio-cultural factors, classroom dynamics, and teacher biases are some of the factors that contribute to this disparity. Studies have shown that gender-responsive teaching strategies, such as Team-based and Project-based learning can help mitigate these differences by providing equal opportunities for male and female students to contribute, collaborate, and lead³⁰.

In the Nigerian context, the traditional education system has often been criticized for its gender biases, with teaching materials and instructional methods inadvertently reinforcing gender stereotypes. These biases can affect students' self-esteem and academic engagement, especially among female students. Adopting Team-based Learning and Project-based Learning strategies could potentially offer a more inclusive learning environment, allowing both male and female students to perform at their best³¹. By structuring group activities and projects in a way that values contributions from all students, these methods could foster greater equity in learning outcomes, particularly in Ecology where both conceptual understanding and hands-on experimentation are important.

Gender-responsive pedagogy, which aims to address the different needs of male and female students, has gained traction in recent years. Studies suggest that active learning strategies, such as team-based learning and project-based learning, are more likely to close gender gaps in academic performance compared to traditional teaching methods³². By fostering a more inclusive classroom environment, these strategies could provide both male and female students with equal opportunities to excel in Biology. In Nigeria, where gender inequality in education remains a challenge, adopting such inclusive strategies could contribute to broader educational equity goals.

Studies have also highlighted the need for gender-sensitive assessment practices in collaborative learning environments. Traditional assessment methods may not adequately capture the contributions and learning progress of each student in a group setting, which could inadvertently disadvantage female students³³. Gender-sensitive could ensure that both male and female students are fairly allowing teachers to better understand the effects of team-based learning and project-based learning across genders.

In terms of collaborative learning strategies like team-based learning and project-based learning, research indicates that female students can benefit significantly from the supportive, interactive nature of these approaches. Collaborative learning environments often help reduce anxiety and foster confidence among female students, leading to more active participation and improved performance^{34,35}. Nevertheless, understanding the role of the effectiveness of team-based learning and project-based learning is critical for designing equitable and inclusive educational strategies that address the unique needs of both male and female students.

While team-based learning and project-based learning have been extensively studied in the context of science education, research on their specific application within Ecology education in Nigerian secondary schools is limited. This study addressed this gap by determining the effects of team-based learning and project-based learning on Senior Secondary School Students' achievement in Ecology in the Abeokuta Metropolis, Nigeria. Additionally, this research will explore how gender may influence the effectiveness of these strategies, providing insights into the dynamics of collaborative learning in science education. By focusing on team-based learning and project-based learning in Ecology, this study aims to contribute to the development of instructional strategies that enhance students' understanding of ecological concepts and improve their academic performance.

1.2 Statement of the Problem

The performance of students in the WAEC Biology examination in Ogun State has shown a gradual improvement from 2020 to 2024, despite previous fluctuations. The pass rate at the credit level (C6 and above) rose from 51.4% in 2020; a decline likely due to the COVID-19 pandemic to 58.2% in 2021, 58.9% in 2022, 61.4% in 2023, and 63.3% in 2024, marking the highest achievement in recent years^{2,3}. This upward trend reflects the impact of improved teaching strategies, enhanced practical learning, and better curriculum implementation. However, WAEC Chief Examiners' reports highlight persistent challenges, particularly in Ecology, where students struggle with critical thinking, analytical reasoning, and real-world application of biological concepts. To sustain and accelerate this progress, a shift from traditional lecture-based methods to

more active learning strategies, such as team-based and project-based learning, is crucial. These strategies can foster deeper conceptual understanding, promote collaboration, and bridge gender disparities in science education. Strengthening teacher preparation, laboratory resources, and student-centered instructional methods will be essential in ensuring long-term academic success in Ecology. This study therefore determined the effect of team-based and project-based learning strategies on Senior Secondary School Students' Achievement in Ecology, with a focus on gender difference, in Ogun State, Nigeria.

1.3 Aim and Objectives of the Study

The aim of this study is to determine the effects of team and project-based learning strategies on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria. The objectives were to:

- i. determine the main effect of Team-based learning strategy on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria;
- ii. determine the main effect of Project-based learning strategy on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria;
- iii. examine the main effect of gender on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria; and
- iv. examine the interaction effect of Team-based learning strategy, Project-based learning strategy and gender on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria.

1.4 Hypotheses

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

- H₀₁:** There will be no significant main effect of team-based learning strategy on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria.
- H₀₂:** There will be no significant main effect of project-based learning strategy on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria.
- H₀₃:** There will be no significant main effect of gender on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria.
- H₀₄:** There will be no significant interaction effect of team-based learning strategy, project-based learning strategy and gender on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria.

1.5 Significance of the Study

The effects of Team-based and Project-based learning strategies on senior secondary school students' achievement in Ecology holds great importance for educators, policymakers, curriculum developers, and other stakeholders. Since Ecology is a major component of the Biology curriculum, understanding how collaborative teaching methods affect student performance can shape more effective teaching and learning practices.

This study offers valuable evidence for policymakers to support the integration of these strategies into educational reforms, especially as they promote critical thinking, collaboration, and real-world problem-solving. It also informs decisions on teacher

training by emphasizing hands-on, student-centered methods. Curriculum developers can use the findings to design interactive Ecology lessons that actively engage students through teamwork and practical tasks. By aligning content with strategies that foster deeper learning, curriculum design becomes more meaningful and effective.

For school administrators, the study encourages investment in resources and professional development to support these learning approaches. It may also influence school structures, such as scheduling, to better accommodate group-based activities. Teachers stand to benefit by gaining insight into strategies that improve student understanding and engagement. With evidence of positive outcomes, they can confidently adopt these methods to create inclusive classrooms that promote active participation and collaborative learning. Students, as the primary beneficiaries, are empowered through these approaches to take charge of their learning. Team-based and project-based tasks not only enhance understanding of Ecology but also help develop communication, critical thinking, and teamwork skills; abilities essential beyond the classroom. Parents gain confidence in knowing that these teaching strategies can support their children's academic and personal growth. This understanding may encourage them to provide support for project-based activities at home.

The study also contributes to the broader field of science education research in Nigeria. It opens avenues for further exploration, such as long-term impacts, implementation challenges, and effectiveness across different subjects or learning environments. Educational technology developers can draw from the study to design tools that support collaborative learning, improve project management, and enhance engagement in Ecology classrooms.

1.6 Scope of the Study

This study determined the effect of team-based learning and project-based learning strategies on the academic achievement of Senior Secondary School Students in Ecology within the context of public secondary schools in the Abeokuta Metropolis, Ogun State, Nigeria. The study covered Senior Secondary Schools within this Metropolis. This urban setting represents a diverse student population with access to varying resources and educational support. By focusing on this location, the study aims to understand how team-based learning and project-based learning strategies function in an urban Nigerian school environment, where resource availability and students' engagement levels may vary significantly.

The study targets Senior Secondary School Students, typically in SS2, as they are at an advanced stage of secondary education where Ecology is intensively covered. This group is well-positioned to engage with team-based learning and project-based learning activities, which require a certain level of maturity, collaborative skills, and content knowledge. The study determined these learning strategies to improve understanding and academic outcomes among students in this age group.

The study focused specifically on Ecology, a major component of the Senior Secondary School Biology curriculum. The study specifically determines the effects of team-based learning and project-based learning on students' academic performance in Ecology. The study was conducted over eight weeks in academic term to allow sufficient time for the implementation of team-based learning and project-based learning strategies in the curriculum. This period is expected to provide measurable outcomes on students' academic achievement and comprehension in Ecology, enabling the study to capture any

short-term effects on learning outcomes. Academic achievement in Ecology was measured through pre- and post-assessments, including tests, quizzes, and project evaluations. These assessments measured students' understanding and retention of ecological concepts before and after exposure to team-based learning and project-based learning strategies.

1.7 Limitation of the Study

The following limitations were encountered throughout the course of conducting this study:

Time Constraints: The academic calendar and examination schedules limited the duration available for the intervention and data collection.

Inconsistent Student Attendance: Irregular student attendance during the intervention period affected participation and the reliability of post-test results.

Environmental Distractions: Noise, overcrowded classrooms, or inadequate ventilation in some schools may have impacted teaching and learning effectiveness.

Data Collection Delays: Delays in retrieving complete test scripts and permissions from school authorities slowed down the data analysis process.

1.8 Operational Definitions of Terms

Academic Achievement: Refers to students' test scores on the Ecology Achievement Test (EAT) before and after being taught using team-based, project-based and traditional strategy.

Ecology: Covers topics in the senior secondary Biology syllabus, such as ecosystems, energy flow, and biodiversity, which are the focus of this study.

Team-Based Learning: A group learning strategy used in this study where students work together to improve their understanding and performance in Ecology.

Project-Based Learning: A hands-on learning strategy used in this study where students carry out projects individually on ecological topics to enhance their grasp and academic outcomes in Ecology.

Traditional Learning Strategy: The conventional classroom methods used to teach students.

Gender: Classifies participants as male or female, used in this study to examine potential differences in Ecology performance across teaching strategies.

Senior Secondary School Students: These are students in Senior Secondary II (SS II), typically between the ages of 15 and 18, who are currently enrolled in Biology classes and formed the participant group for this study.

Endnotes

1. S. O. Egwu & E. C. Okigbo, *Effect of Field Trip on Secondary School Students' Academic Achievement in Ecology in Anambra State*, **South Eastern Journal of Research and Sustainable Development (SEJRSD)**,4(1), 2021, 140 – 156.
2. N. Lawal, *Lagos vs Ogun, Abia vs Anambra: List of States with the better WAEC Results in 7 years*, 2022. Available online: <https://www.legit.ng/education/1487754-lagos-ogun-abia-anambra-states-waec-results-7-years/>
3. O. U. Oguguo & U. V. Uboh, *State Based Analysis of Candidates' WASSCE Participation and Achievement of Five Credits Passes and above including Mathematics and English Language in Nigeria*, **International Journal of Advanced Academic Research (Sciences, technology and Engineering)**, 6(6), 2020, 42 – 53. Available online: DOI: 10.46654/ij.24 889849.e6619
4. O. K. Kilag, R. Tariman, R. A. Dela Cruz, G. Cantere Jr., L. Niere & V. Priolo, *Innovative Teaching Strategies in Secondary Science Education: A Systematic Review*, **International Multidisciplinary Journal of Research for Innovation, Sustainability, and Excellence (IMJRISE)**, 1(4), 2024, 37-44. Available online: <https://risejournals.org/index.php/imjrise/article/view/247>
5. I. Mohammed, H. Zakari, J. M. Bako, Y. Isa, Y. Abdullahi & A. G. Jibrin, *Impact of Project-based Learning Strategy on Academic Performance of Secondary School Students in Ecology in Bauchi State*, **Journal of Science Technology and Education**, 11(4), 2023, 1 – 8.
6. S. Carlos, S. Neucir, F. Frederico, P. Lucas, P. Victor, T. Ana, C. Bruno, C. Renata, V. M. Rita & W. Benjamin, *Effectiveness of Active Learning for Ecology Teaching: The Perspective of Students vs their Grades*, 2020, 1 – 34, Available online: DOI:10.1101/2020.04.02.021584.
7. S. G. Isa, M. A. Mammam, Y. Badar & T.Bala, *The Impact of Teaching Methods on Academic Performance of Secondary School Students in Nigeria*, **International Journal of Development Research**, 10(06), 2020, 37382-37385.
8. S. Mukandayisenga, D. Opanga, V. Nsengimana, *Teachers' Perceptions on the Effectiveness of the Inquiry-Based Learning towards Students' Achievement in Biology: The Case of schools of Rwanda*, **African Journal of Educational Studies in Mathematics and Sciences**, 17(2), 2021, 1-10. Available online: DOI: <https://dx.doi.org/10.4314/ajesms.v17i2.895>
9. N. C. Vu, J. F. Hooker & C. J. Simonds, *Cooperative, Competitive, or Individualistic? Exploring the Role of Social Interdependence in the Classroom*, **Communication Education**, 70(3), 2021, 247-265.

10. A. Sibomana, C. Karegeya & J. Sentongo, *Effect of Cooperative Learning on Chemistry Students' Achievement in Rwandan Day-Upper Secondary Schools*, **European Journal of Educational Research**, 10(4), 2021, 2079-2088.
11. A. Burgess & E. Matar, Team-based learning (TBL): Theory, Planning, Practice, and Implementation. In *Clinical Education for the Health Professions: Theory and Practice*, Singapore: Springer Nature Singapore, 2023, 1325-1353.
12. A. Wullschleger, A. Vörös, B. Rechsteiner, A. Rickenbacher & K. M. Merki, *Improving Teaching, Teamwork, and School Organization: Collaboration Networks in School Teams*, **Teaching and Teacher Education**, 121, 2023, 103909.
13. O. Ajewole & T. Bello, *Effect of Team-based Instructional Strategy on Junior Secondary School Students' Academic Achievement in Basic Science in Ile-Ife, Osun State, Nigeria*, **International Journal of Contemporary Issues in Education**, 4(2), 2022, 11-17.
14. S. Nawabi, R. Bilal & M. Q. Javed, *Team-based Learning versus Traditional Lecture-Based Learning: An Investigation of Students' Perceptions and Academic Achievements*, **Pakistan Journal of Medical Sciences**, 37(4), 2021, 1080.
15. M. Sweet & L. K. Michaelsen, *Team-based Learning in the Social Sciences and Humanities: Group Work that Works to Generate Critical Thinking and Engagement*, Taylor & Francis, 2023.
16. C. G. P. Dean, P. Grossman, L. Enumah, Z. Herrmann & S. S. Kavanagh, *Core Practices for Project-based Learning: Learning from Experienced Practitioners in the United States*, **Teaching and Teacher Education**, 133, 2023, 104275.
17. N. G. Ikegbusi & J. U. Ekwu, Impact of Project-based Learning and Student Creativity on Academic Achievement of Public Secondary School Students in Abia State, **Int'l Journal of Education Research and Scientific Development**, 5(5), 2024, 14-14.
18. S. Koes-H & N. D. Putri, *The Effect of Project-based Learning in STEM on Students' Scientific Reasoning*, In **Journal of Physics: Conference Series**, 1835(1), 2021, 012006.
19. H. B. Issa & A. Khataibeh, *The Effect of Using Project Based Learning on Improving the Critical Thinking among Upper Basic Students from Teachers' Perspectives*, **Pegem Journal of Education and Instruction**, 11(2), 2021, 52-57.
20. T. M. Derkach, M. Bilianska & O. G. Yaroshenko, *Project-based Learning as an Approach to Enhance Ecological Component in Professional Education*, **Educational Technology Quarterly**, 2023(4), 2023, 481-497.

21. N. J.Ogunode, *Basic Education in Nigeria: Challenges and Way Forward*, **Journal of Intellectual Property and Human Rights**, 1(2), 2022, 1-13.
22. L. M. Arcila Hernández, K. R. Zamudio, A. G. Drake & M. K.Smith, *Implementing Team-Based Learning in the Life Sciences: A Case Study in an Online Introductory Level Evolution and Biodiversity Course*, **Ecology and Evolution**, 11(8), 2021, 3527-3536.
23. O. Haatainen & M. Aksela, *Project-based Learning in Integrated Science Education: Active Teachers' Perceptions and Practices*, **LUMAT: International Journal on Math, Science and Technology Education**, 9(1), 2021, 149-173.
24. D. Ramdani & H. Susilo, *The Effectiveness of Collaborative Learning on Critical Thinking, Creative Thinking, and Metacognitive Skill Ability: Meta-Analysis on Biological Learning*, **European Journal of Educational Research**, 11(3), 2022, 1607-1628.
25. C. L. Eheazu, *Promoting Conservation Agriculture in Rural Nigeria: Relevance of Environmental Literacy Education*, **International Journal of Agricultural Extension and Rural Development Studies**, 10(1), 2023, 16-37.
26. B. J. Akounjom, O. Babatunde & O. M. Aiguobarueghian, *The Future of Vocational Education Trends and Innovations in Blended Teaching Methodologies in Nigeria*, **International Journal of Sub-Saharan African Research**, 2(3), 2024, 267-277.
27. K. N. Kuteesa, C. U. Akpuokwe & C. A. Udeh, *Gender Equity in Education: Addressing Challenges and Promoting Opportunities for Social Empowerment*, **International Journal of Applied Research in Social Sciences**, 6(4), 2024, 631-641.
28. A. N. Farley & B. Leonardi, *Beyond Bathroom Bills and the Gender Identity Debate: Complicating the Policy Conversation about Supporting Trans Students in Schools*, **Educational Policy**, 35(2), 2021, 274-303.
29. A. I. Oladejo, N. C. Nwaboku, P. A. Okebukola & I. A. Ademola, *Gender Difference in Students' Performance in Chemistry–Can Computer Simulation Bridge the Gap?*, **Research in Science & Technological Education**, 41(3), 2023, 1031-1050.
30. O. T. Adeosun & K. E. Owolabi, *Gender Inequality: Determinants and Outcomes in Nigeria*, **Journal of Business and Socio-economic Development**, 1(2), 2021, 165-181.

31. U. Kabir, A. H. Marty, B. Akinrinmade & S. S. Zuilkowski, *An Analysis of Teaching and Learning Materials for Literacy Instruction in Kano State, Nigeria: Curricular Relevance, Cultural Responsiveness and Gender Equity*, **Literacy**, 56(2), 2022, 130-149.
32. M. Abrha, A. D. Kelkay & A. Seifu, *Gender Responsive Pedagogy Practices: Secondary School Science Teachers in Ethiopia*, **Journal of International Women's Studies**, 25(1), 2023, 20.
33. M. Putria, *Gender Equality Analysis in the Learning Process (Case Study on Accounting Department at Vocational High School)*, **International Journal of Health, Education & Social (IJHES)**, 7(11), 2024, 61-86.
34. F. N. Ezeaku, E. A. Onu, P. U. Agu, E. C. Edikpa, B. N. Nwafor, A. N. Ozioko & C. S. Ugwuanyi, *Appraisal of Quality Assurance Measures in the Management of Secondary Schools and its Implication on Science, Technology, Engineering and Mathematics Education*, **International Journal of Mechanical and Production Engineering Research and Development**, 10(1), 2021, 159-170.
35. M. P. Osiesi, S. A. Adeniran, A. F. Adekoya, O. D. Akomolafe, A. L. Aruleba & S. Blignaut, *Gender Disparities and Teachers' Soft Skills as Determinants of Learners' Attitude Towards Learning Mathematics in Ekiti State Primary Schools, Nigeria*, **Gender and Behaviour**, 20(4), 2022, 20788-20802.

Chapter Two Literature Review

This chapter presents comprehensive review of related literature and it is organized into the following subheadings:

2.1 Conceptual Review

2.1.1 Academic Achievement

2.1.2 Biology

2.1.3 Ecology

2.1.4 Teaching Strategies

2.1.4.1 Team-based Learning Strategy

2.1.4.2 Project-based Learning Strategy

2.1.4.3 Traditional Teaching Strategy

2.1.5 Gender

2.2 Theoretical Framework

2.2.1 Constructivist Learning Theory

2.3 Review of Empirical Studies

2.3.1 Team-based Learning Strategy and Academic Achievement in Ecology

2.3.2 Project-based Learning Strategy and Academic Achievement in Ecology

2.3.2 Gender and Academic Achievement in Ecology

2.4 Conceptual Model

2.5 Summary of Literature Reviewed

2.1 Conceptual Review

2.1.1 Academic Achievement

Academic achievement refers to the measurable performance of a student in educational activities, typically reflected in test scores, grades, and other forms of assessments. It is an indicator of the extent to which a student has acquired, understood, and can apply knowledge and skills in specific subjects or academic areas. Academic achievement is a key concept in education as it reflects not only the effectiveness of teaching and learning but also the progress and development of students within the educational system¹.

Academic achievement involves the mastery of cognitive skills and knowledge in specific subject areas. For example, in Ecology, this means understanding fundamental concepts such as ecosystems, biodiversity, and energy flow. Cognitive mastery is typically measured through tests and exams that assess knowledge retention, comprehension, and the ability to apply learned concepts. Besides cognitive understanding, academic achievement also encompasses the development of critical thinking, problem-solving, analytical reasoning, and practical application skills. In subjects like Biology and Ecology, students must not only learn theoretical content but also demonstrate their ability to apply knowledge in experiments, real-world situations, and environmental problem-solving².

Academic achievement is influenced by students' motivation, engagement, and attitudes toward learning. A positive attitude toward the subject and active participation in class activities, projects, and group work are often correlated with higher levels of academic success. Behavioral engagement includes students' attendance, participation in

class discussions, and commitment to completing assignments. Various tools and methods are used to evaluate academic achievement, including standardized tests, teacher-made exams, quizzes, assignments, and practical assessments like projects and experiments. These tools help to measure not only students' knowledge but also their application of skills and concepts in different contexts³.

The way subjects are taught has a profound effect on academic achievement. Student-centered approaches like Team-based Learning and Project-based Learning, which encourage collaboration, active learning, and practical application, have been found to improve students' academic outcomes compared to traditional teacher-centered methods, which are more focused on memorization and passive learning. Students who are highly motivated and interested in a subject tend to perform better academically. This can be influenced by various factors, such as the relevance of the subject to their future goals, teaching methods that make learning engaging, and the availability of support systems like peer collaboration and teacher guidance⁴. The quality of the learning environment, including classroom resources, teacher-student interactions, and peer support, plays a crucial role in academic achievement. Positive, interactive, and well-resourced learning environments foster better academic outcomes by encouraging student participation and engagement⁵.

Academic achievement is a multifaceted concept that encompasses not only knowledge acquisition but also the development of critical skills, attitudes, and behaviors that contribute to students' overall educational success⁶. In the context of this study, understanding the concept of academic achievement in Ecology is crucial for determining how different teaching methods influence students' learning outcomes and addressing

factors such as gender disparities. Ecology, as a subfield of Biology, requires students to understand complex concepts about the interactions between organisms and their environment. Academic achievement in Ecology is not only measured by students' ability to recall factual information but also by their capacity to apply ecological concepts to real-world environmental challenges, such as biodiversity loss, climate change, and conservation efforts⁷.

In this study, academic achievement in Ecology is evaluated through students' performance in exams, practical projects, and their ability to apply theoretical knowledge in hands-on ecological tasks. The study compares how Team-based and Project-based learning strategies influence students' academic achievement in Ecology, assessing whether these approaches foster deeper learning, critical thinking, and practical application of knowledge. By assessing students' academic achievement, educators can determine the effectiveness of their teaching methods. If students consistently perform poorly, it may indicate a need to adopt more innovative and interactive instructional strategies, such as Team-based Learning and Project-based Learning.

Academic achievement scores help identify specific areas where students are struggling, allowing educators to provide targeted interventions. For instance, in Ecology, students may struggle with abstract concepts like energy flow in ecosystems, and teachers can modify instruction to address these gaps. Academic achievement data is critical for policymakers to make informed decisions about curriculum design, teaching strategies, and resource allocation. Improving student performance in subjects like Ecology is important for addressing global environmental challenges and promoting sustainable development⁵. Assessing academic achievement also helps in identifying gender

disparities or socio-economic gaps in student performance. In this study, a focus on gender differences will provide insights into how instructional strategies like team-based learning and project-based learning can either mitigate or exacerbate these gaps, ensuring that all students, regardless of gender, have equal opportunities to succeed.

2.1.2 Biology

Biology is the branch of science that studies life and living organisms, encompassing their structure, function, growth, evolution, and interactions within ecosystems. Rooted in the Greek words "bios" (meaning life) and "logos" (meaning study), Biology seeks to understand the fundamental principles that govern life processes, from the microscopic molecular level to the global scale of ecosystems. It is a broad and interdisciplinary field that overlaps with many other scientific disciplines, including chemistry, physics, and environmental science, each contributing to a more holistic understanding of life⁸.

One of the central themes in Biology is the concept of the cell, recognized as the basic unit of life. The cell theory, developed in the 19th century, established that all living organisms are composed of cells, and all cells arise from pre-existing cells. This discovery transformed Biology, as it provided a universal framework for studying life. Within this framework, cellular Biology, or cytology, explores the structure, function, and processes within cells, including how cells divide, obtain energy, and maintain homeostasis. Advances in cellular Biology have paved the way for understanding more complex biological concepts, such as genetics, molecular Biology, and physiology⁹.

Cell theory states that all living organisms are composed of cells, which are the basic units of life. It also emphasizes that all cells arise from pre-existing cells. Gene theory posits that traits are inherited through genes, which are segments of DNA that encode information for protein synthesis and biological functions. The theory of evolution by natural selection explains how species adapt and evolve over time through genetic variations and environmental pressures. Homeostasis refers to the ability of organisms to maintain stable internal conditions despite external changes. This is crucial for survival and proper functioning. Biological systems are characterized by interdependence, where organisms interact with each other and their environments in complex ways. This principle highlights the importance of ecological relationships and biodiversity^{8,9}.

Genetics is another core component of Biology that studies heredity and variation in organisms. The foundation of genetics lies in the discovery of DNA (deoxyribonucleic acid), the molecule that carries genetic information. DNA encodes the instructions for building and maintaining organisms and is passed from one generation to the next. Through the processes of replication, transcription, and translation, DNA sequences are used to create proteins, the molecular machines that perform most of the functions within cells. Mendelian genetics, the study of how traits are inherited according to rules discovered by Gregor Mendel, provides insight into inheritance patterns and genetic variation. Modern genetics has expanded to include molecular genetics, genomics, and biotechnology, allowing scientists to manipulate genes, study genetic diseases, and develop genetically modified organisms¹¹.

Evolution is a foundational theory in Biology that explains how species change over time through the processes of natural selection and genetic drift. Charles Darwin's theory of evolution, first published in *On the Origin of Species* in 1859, revolutionized our understanding of life's diversity. According to Darwin, organisms with advantageous traits are more likely to survive and reproduce, passing those traits to their offspring. This process of natural selection leads to adaptation, where populations of organisms become better suited to their environment over generations. Evolutionary Biology studies the origins and diversity of life, helping to explain relationships between species, the development of new species, and the adaptation of organisms to changing environments¹².

Another key concept in Biology is Ecology, the study of interactions between organisms and their environment. Ecology examines how organisms interact with each other and with abiotic (non-living) components such as climate, soil, and water. These interactions form ecosystems, complex networks of organisms and their physical surroundings that function as interconnected systems. Ecologists study energy flow, nutrient cycling, and population dynamics within ecosystems to understand how organisms are influenced by their environment and how they contribute to ecosystem stability. In an era of global environmental change, Ecology is essential for addressing issues such as biodiversity loss, climate change, and conservation¹³.

Physiology is the study of the functions and mechanisms of living organisms, focusing on how organs and systems within an organism work individually and together to sustain life. This includes the study of respiration, digestion, circulation, and reproduction, as well as the ways organisms maintain homeostasis; a stable internal environment despite external fluctuations. For example, human physiology explores how

our bodies regulate temperature, pH, and glucose levels to ensure survival. Comparative physiology extends these studies across different species, helping scientists understand how organisms adapt their physiological processes to meet the demands of diverse environments⁹.

Behavioral Biology examines how organisms interact with their environment and each other through behavior, which can include finding food, mating, and defending territory. Behavioral biologists study the neurological and genetic bases of behavior, investigating how behaviors evolve and contribute to survival and reproduction. Social behaviors, such as cooperation and communication, are especially significant in species with complex social structures, such as humans, primates, and some bird and insect species. Ethology, a branch of behavioral Biology, observes animals in their natural habitats to understand how behaviors are influenced by evolutionary pressures^{11,14}.

At a broader level, Biology is divided into several branches based on the scale of study, the types of organisms studied, and specific biological processes. Micro Biology studies microscopic organisms like bacteria, viruses, and fungi, playing a crucial role in medicine, industry, and environmental science. Botany focuses on plants, including their structure, growth, and ecological importance. Zoology examines animals, exploring their anatomy, physiology, behavior, and evolution. These branches, along with others like marine Biology, paleontology, and biochemistry, provide a diverse framework for understanding life on Earth¹⁵.

Biology has vast practical applications across multiple fields. In medicine, Biology underpins our understanding of the human body, disease mechanisms, and treatment development. Pharmacology, immunology, and pathology, for example, are all

grounded in biological concepts. Biotechnology applies biological knowledge to develop new products and technologies, such as genetically engineered crops, pharmaceuticals, and biofuels. Conservation Biology uses ecological principles to protect biodiversity and manage natural resources, a critical task in the face of global challenges like deforestation and climate change^{8,15}.

The methods used in biological research are diverse and sophisticated, ranging from fieldwork and observations to laboratory experiments and computational models. Modern Biology relies heavily on technologies like microscopy, DNA sequencing, and bioinformatics to analyze and interpret complex biological data. Advances in technology have accelerated biological research, enabling breakthroughs in areas such as genomics, synthetic Biology, and regenerative medicine. For instance, CRISPR-Cas9, a gene-editing technology, has revolutionized genetics by allowing precise modifications to DNA, opening up possibilities for treating genetic disorders^{9,15}.

The significance of Biology extends beyond scientific research; it influences society in profound ways. Understanding biological concepts is essential for addressing pressing global issues, such as pandemics, food security, and environmental degradation. Biology education empowers individuals to make informed decisions about health, nutrition, and environmental conservation. Furthermore, as biotechnology and genetic engineering advance, ethical considerations in Biology become increasingly relevant, raising questions about genetic modification, cloning, and biodiversity preservation¹⁶.

Biology helps us comprehend the fundamental processes that govern life, from cellular functions to complex ecosystems. This knowledge is essential for advancing scientific research and technology. Biological research underpins medical science,

leading to advancements in healthcare, disease prevention, diagnosis, and treatment. Understanding human Biology, genetics, and immunology is crucial for developing vaccines, therapies, and medical technologies. Biology informs conservation efforts by helping us understand the interrelationships between organisms and their environments. This knowledge is vital for protecting biodiversity and addressing environmental challenges such as climate change, habitat destruction, and pollution. Biological principles are applied in agriculture to improve crop yield, pest resistance, and sustainable farming practices. Advances in plant and animal Biology contribute to food security and agricultural sustainability. Biology plays a key role in biotechnology, where biological systems are utilized for industrial and medical applications. This includes genetic engineering, biopharmaceuticals, and biofuels, which have transformative impacts on society. Biology fosters scientific literacy and critical thinking skills, promoting an understanding of health, Ecology, and the natural world. Educating individuals about biological principles is essential for informed decision-making regarding health, environment, and policy^{8,9,15}.

Biology is a vast and dynamic field that seeks to understand the complexities of life on Earth. From the cellular level to entire ecosystems, the study of Biology provides insights that are essential for advancing knowledge, improving health, and addressing environmental challenges. As a foundational science, Biology informs various disciplines and plays a crucial role in shaping our understanding of the natural world and our place within it. In the context of this study, understanding biological concepts, particularly in Ecology, is vital for enhancing teaching strategies and improving student outcomes in Biology education^{13,17}.

In conclusion, Biology is a multifaceted science that seeks to unravel the mysteries of life by exploring its complexity, diversity, and underlying principles. From the molecular level to ecosystems, Biology provides a comprehensive framework for understanding the mechanisms that sustain life. The field continues to evolve, fueled by technological advancements and interdisciplinary approaches that deepen our understanding of life on Earth. By exploring the intricate connections between organisms and their environments, Biology offers insights that are essential for human well-being, environmental stewardship, and the sustainable management of resources for future generations¹⁷.

2.1.3 Ecology

Ecology is the branch of Biology that studies the relationships between living organisms and their interactions with their physical environment. Derived from the Greek words "oikos" (meaning house or environment) and "logos" (meaning study), Ecology explores how organisms interact with each other and with their surroundings, forming complex webs of life. It encompasses the study of ecosystems, communities, populations, and the environmental factors that influence life processes. Understanding Ecology is essential as it provides insights into how biodiversity, natural resources, and environmental health are maintained and how human activities impact ecosystems¹³.

The concept of Ecology is rooted in the idea of interdependence among organisms and their environment. Each organism, from microscopic bacteria to towering trees and animals, plays a specific role within its ecosystem. These roles, or ecological niches, define how organisms obtain resources, reproduce, and interact with others. For instance,

plants serve as primary producers in most ecosystems, converting sunlight into energy through photosynthesis, which forms the basis of the food chain. Herbivores consume plants, carnivores eat herbivores, and decomposers break down dead matter, returning essential nutrients to the soil. This interconnected system, known as a food web, is fundamental to ecosystem stability and resilience¹⁸.

One of the core areas of Ecology is the study of ecosystems, which are communities of organisms interacting with each other and with their physical environment. Ecosystems can vary widely in size and complexity, from small ponds to vast rainforests and coral reefs. Within an ecosystem, energy flows through different trophic levels, or stages of the food chain, beginning with primary producers and moving through various levels of consumers to decomposers. This energy flow is crucial for sustaining life, as each trophic level depends on the one below it. Ecosystems also involve nutrient cycles, where essential elements like carbon, nitrogen, and water circulate through living organisms and the environment. These biogeochemical cycles are vital for sustaining life and maintaining ecosystem balance¹⁹.

The concept of the biosphere; Earth's global ecosystem, encompasses all ecosystems on the planet. The biosphere is divided into biomes, large geographic areas characterized by distinct climates, vegetation, and animal life. Examples include tropical rainforests, deserts, grasslands, and tundra. Each biome has unique abiotic (non-living) factors, such as temperature, rainfall, and soil composition, which shape the types of organisms that can thrive there. Understanding biomes is fundamental in Ecology, as it helps scientists' study how climatic factors influence biodiversity and how different ecosystems contribute to the global balance of life^{18,19}.

Population Ecology is another critical area within Ecology, focusing on the dynamics of species populations within an ecosystem. Population ecologists study factors that influence population size, growth rate, and distribution, including birth rates, death rates, and migration. Populations are regulated by various factors, such as availability of resources, predation, disease, and competition. Concepts like carrying capacity, the maximum number of individuals an environment can support sustainably; are essential in understanding population growth and its implications for ecosystem health. Population studies are particularly relevant in the context of conservation Biology, as they provide insights into species that may be at risk of extinction²⁰.

Community Ecology examines interactions among different species within a particular area or ecosystem. These interactions include competition, predation, mutualism, and parasitism, each of which shapes community structure and function. For example, in mutualistic relationships, both species benefit, as seen in pollination, where insects obtain nectar from flowers while assisting in the plant's reproduction. Conversely, in competitive interactions, species vie for the same resources, which can limit population sizes and alter community composition. By studying these relationships, ecologists can understand the factors that promote species diversity and stability within communities^{13,19}.

A key principle in Ecology is the concept of ecological succession, the process by which ecosystems change and develop over time. Succession can be primary, occurring on newly formed or barren landscapes with no previous life, or secondary, happening after a disturbance, such as a fire or flood, that disrupts an existing community. Through succession, ecosystems gradually progress from simple to more complex communities. For example, in primary succession, lichens and mosses may colonize bare rock, paving

the way for grasses, shrubs, and eventually trees. Succession plays a critical role in ecosystem resilience and recovery, demonstrating the dynamic nature of ecological communities²¹.

Biodiversity, the variety of life within an ecosystem, is a central concept in Ecology. It includes species diversity, genetic diversity, and ecosystem diversity, each contributing to the overall health and resilience of ecosystems. High biodiversity generally indicates a stable ecosystem, as a greater variety of species can better withstand environmental changes and disturbances. Biodiversity is crucial for ecosystem services; benefits that ecosystems provide to humans, such as clean water, fertile soil, and pollination. However, human activities, such as deforestation, pollution, and climate change, threaten biodiversity worldwide, leading to a loss of ecosystem services and an increased risk of ecosystem collapse^{19,21}.

Ecologists also study the interactions between organisms and their abiotic environment, which includes factors like temperature, water, sunlight, and soil. These abiotic factors influence the distribution, behavior, and physiology of organisms, shaping ecosystem structure and function. For instance, plants in arid regions have adaptations like deep roots or water-storing tissues to survive in dry conditions. Likewise, animals in cold climates may develop thicker fur or hibernate to cope with low temperatures. These adaptations highlight the intricate relationship between organisms and their environment, a concept central to ecological studies^{22,23}.

Human Ecology examines how human populations interact with the environment and the impact of human activities on ecosystems. With the rapid growth of human populations and industrialization, human activities have become a dominant force

shaping ecosystems globally. Activities like deforestation, pollution, urbanization, and resource exploitation disrupt ecosystems, leading to habitat loss, climate change, and declining biodiversity. Ecologists study these impacts to understand how human actions alter natural systems and to develop strategies for sustainable resource management and conservation²³.

The concept of ecological footprint, which measures the impact of human activities on the environment, is also significant in Ecology. It quantifies the amount of land and resources needed to sustain a population's lifestyle, helping societies assess their resource use and environmental impact. High ecological footprints indicate unsustainable practices that deplete natural resources faster than they can be replenished. By reducing ecological footprints, societies can work toward sustainable development, which meets human needs without compromising the health of ecosystems^{13,21,23}.

Conservation Ecology focuses on protecting and restoring biodiversity, emphasizing the need to preserve species, habitats, and ecosystems. Conservationists aim to mitigate threats to biodiversity, such as habitat destruction, invasive species, and overexploitation. Protected areas, such as national parks and wildlife reserves, are established to safeguard vulnerable species and ecosystems. Conservation efforts also include restoration Ecology, which seeks to rehabilitate degraded ecosystems to restore their structure, function, and biodiversity. Conservation Ecology is vital in addressing the ecological crises posed by human activities, ensuring that future generations inherit a healthy and diverse planet²⁴.

In recent years, climate change has become a central issue in Ecology, affecting ecosystems and species distributions worldwide. Rising temperatures, changing

precipitation patterns, and extreme weather events disrupt ecosystems, forcing species to adapt, migrate, or face extinction. Polar regions, coral reefs, and tropical rainforests are among the ecosystems most vulnerable to climate change. Ecologists study these impacts to predict future changes, inform conservation efforts, and develop strategies for climate resilience^{22,24}.

Ecology provides insights into how ecosystems operate, including energy flow, nutrient cycling, and species interactions. This knowledge is essential for understanding environmental processes and dynamics. Ecological principles are fundamental for conservation efforts. By understanding ecosystems and their components, ecologists can develop strategies to protect biodiversity, restore degraded habitats, and manage natural resources sustainably. Ecology helps identify and analyze environmental problems such as climate change, habitat destruction, pollution, and invasive species. Understanding ecological processes is vital for developing effective solutions to these challenges. Incorporating ecological knowledge into planning and decision-making is essential for sustainable development. This involves balancing human needs with environmental health to ensure the well-being of current and future generations. Teaching ecological concepts fosters awareness of environmental issues and encourages responsible citizenship. An understanding of Ecology empowers individuals to make informed decisions about conservation and environmental stewardship^{13,22,23}.

Ecology is a vital field of study that examines the relationships between organisms and their environments. It encompasses various levels of biological organization, from individuals to ecosystems, and provides critical insights into the functioning of the natural world. As environmental challenges become increasingly

complex, ecological knowledge is essential for fostering sustainability, conservation, and a deeper appreciation of the interconnectedness of life on Earth. In the context of education, particularly in teaching Biology and Ecology, understanding ecological principles is crucial for developing effective teaching strategies that promote student engagement and learning outcomes^{23,24}.

Ecology is an interdisciplinary science that draws on principles from Biology, chemistry, geology, and environmental science to understand the complex interactions within ecosystems. It emphasizes the interconnectedness of life and the importance of maintaining balance within natural systems. As global environmental challenges intensify, Ecology provides the knowledge and tools needed to address issues like biodiversity loss, climate change, and resource depletion. By fostering a deeper understanding of our relationship with the natural world, Ecology plays a critical role in promoting sustainable living and environmental stewardship^{13,24}.

2.1.4 Teaching Strategies

Teaching strategies refer to the methods and techniques that educators employ to facilitate student learning and enhance educational outcomes. These strategies are essential components of the teaching-learning process, as they determine how information is presented, how students engage with the material, and how learning is assessed. Effective teaching strategies take into account the diverse needs of students, their learning styles, and the specific objectives of the curriculum. Direct instruction is a teacher-centered approach where the educator presents information in a structured and systematic manner. This strategy often involves lectures, demonstrations, and explicit

teaching of concepts. While it is effective for conveying factual information and basic skills, it may not engage students in higher-order thinking or promote deep understanding^{25,26}.

Cooperative learning involves students working together in small groups to complete tasks, solve problems, or engage in discussions. This strategy fosters collaboration, communication, and teamwork while encouraging peer learning. Techniques such as think-pair-share, jigsaw, and group projects are commonly used in cooperative learning²⁷. Inquiry-based learning is a student-centered approach that encourages students to ask questions, explore, and investigate topics of interest. This strategy promotes critical thinking, problem-solving, and independent learning. Students actively engage in the learning process by conducting experiments, researching, and drawing conclusions based on evidence²⁸.

Project-based Learning is a teaching strategy where students engage in long-term projects that require them to apply their knowledge to real-world challenges. This approach emphasizes active learning, creativity, and collaboration. Project-based Learning helps students develop critical thinking and practical skills while fostering a deeper understanding of the subject matter²⁹. Team-based Learning is an instructional strategy that combines individual and group learning experiences. Students work in teams to solve problems and apply concepts, enhancing their understanding through peer interaction. Team-based Learning emphasizes accountability, collaboration, and critical thinking, making it particularly effective in higher education and complex subjects³⁰.

Differentiated instruction involves tailoring teaching methods to accommodate the diverse learning needs, interests, and abilities of students. This strategy allows educators

to provide various pathways for students to engage with content, such as through varied instructional materials, groupings, and assessments³¹. In a flipped classroom model, traditional teaching and homework roles are reversed. Students are introduced to new content at home through videos or readings and engage in active learning activities during class time. This strategy allows for more personalized and interactive learning experiences in the classroom. The integration of technology in teaching strategies includes the use of digital tools, multimedia resources, and online platforms to facilitate learning. Technology can enhance engagement, provide instant feedback, and create interactive learning environments³².

The choice of teaching strategies should align with the desired learning outcomes and objectives of the curriculum. Different strategies may be more effective for achieving specific goals, such as developing critical thinking skills or mastering factual knowledge. Understanding the diverse needs, backgrounds, and learning styles of students is crucial when selecting teaching strategies. For example, some students may benefit from collaborative learning, while others may thrive in independent Inquiry-based tasks^{25,28}.

The nature and complexity of the subject matter can influence the choice of teaching strategies. For example, complex topics may benefit from inquiry-based or project-based learning to facilitate deeper understanding and application. The physical and social environment of the classroom can impact the effectiveness of teaching strategies. Factors such as classroom size, available resources, and student-teacher relationships should be considered when designing instructional approaches. The educational context, including the institution's goals, curriculum standards, and available

resources, plays a significant role in determining which teaching strategies are appropriate and feasible^{26,28}.

Effective teaching strategies foster active participation and engagement among students, making learning more enjoyable and motivating. By employing appropriate teaching strategies, educators can enhance students' understanding of concepts, critical thinking skills, and academic achievement. Effective teaching strategies allow educators to address the varied learning styles, preferences, and abilities of students, promoting inclusivity and equity in education. Many modern teaching strategies emphasize collaboration and communication among students, helping them develop essential social and interpersonal skills. Strategies such as project-based learning and team-based learning help students develop skills necessary for success in real-world situations, including problem-solving, teamwork, and critical thinking^{29,30}.

The concept of teaching strategies encompasses a wide range of methods and techniques that educators use to facilitate learning and improve academic outcomes. Understanding and implementing effective teaching strategies are essential for promoting student engagement, enhancing learning, and catering to the diverse needs of students. By selecting the appropriate strategies for their specific context, educators can create dynamic and effective learning environments that prepare students for future challenges^{25,26}. In the context of this study, exploring how team-based and project-based learning strategies impact academic achievement in Ecology will provide valuable insights into effective teaching practices in science education.

2.1.4.1 Team-based Learning Strategy

Team-based learning is an instructional strategy that emphasizes collaboration, active learning, and accountability among students in small groups. It is designed to enhance student engagement, promote critical thinking, and improve learning outcomes by integrating individual and group work³⁰. Team-based learning is particularly effective in higher education settings, but it can also be adapted for use in secondary education, including subjects such as Biology. Before the class, students are assigned readings or materials that provide foundational knowledge on the topic to be discussed. This preparation is crucial for ensuring that all students arrive with a baseline understanding, enabling them to engage meaningfully in group activities³³.

At the beginning of the team-based learning session, students take an individual Readiness Assurance Test (iRAT) to assess their understanding of the pre-class materials. This test typically consists of multiple-choice questions and is designed to reinforce the content covered in the assigned readings. Following the iRAT, students take the same test as a team (tRAT). During this phase, students discuss each question and come to a consensus on the correct answers. This collaborative approach fosters communication, negotiation, and deeper understanding of the material, as students explain their reasoning to one another. After completing the tRAT, the instructor provides immediate feedback on the team's performance. This feedback helps students identify areas of strength and weakness and reinforces their understanding of the concepts³⁴.

The core of team-based learning involves application exercises, where teams work on complex, real-world problems or case studies that require them to apply the knowledge they have gained. These exercises promote higher-order thinking skills, such as analysis, synthesis, and evaluation. Teams are often tasked with solving problems,

making decisions, or presenting their findings to the class. Team-based learning includes a peer evaluation component, where team members assess each other's contributions and collaboration. This encourages accountability within teams and helps ensure that all members are actively participating and contributing to the group's success. In team-based learning, the instructor acts as a facilitator or guide rather than a traditional lecturer. The instructor's role is to provide support, clarify concepts, and encourage group discussions. This shift in the instructor's role allows for a more interactive and dynamic classroom environment^{33,34}.

Team-based learning promotes active participation and engagement among students, as they are required to work collaboratively and contribute to group discussions. This engagement can lead to improved motivation and interest in the subject matter. Research has shown that team-based learning can lead to higher academic achievement compared to traditional teaching methods³⁴. The emphasis on application and problem-solving helps students develop a deeper understanding of the material. Team-based learning encourages students to think critically and apply their knowledge to real-world scenarios. The collaborative nature of the strategy fosters discussions that challenge students to analyze information, evaluate alternatives, and make informed decisions³⁵.

Working in teams helps students develop essential communication and interpersonal skills. They learn to articulate their ideas, listen to others, and work collaboratively towards a common goal, which are valuable skills for their future careers³³. Team-based learning creates a supportive learning environment where students feel more connected to their peers. This sense of community can enhance student satisfaction and reduce feelings of isolation, particularly in larger classes. The individual

and team assessments in team-based learning foster a sense of accountability among students. They recognize that their contributions impact the team's performance, motivating them to engage fully in the learning process³⁰.

The effectiveness of team-based learning can be influenced by group dynamics, including conflicts, varying levels of commitment, and different communication styles. Instructors need to monitor group interactions and provide support to help resolve conflicts. While team-based learning promotes collaboration, it can sometimes be challenging to assess individual contributions accurately. Implementing peer evaluations and individual assessments can help address this issue. Successful implementation of team-based learning requires careful planning and preparation by the instructor. Developing appropriate materials, application exercises, and assessments can be time-consuming. Some students may be resistant to collaborative learning methods, especially if they are accustomed to traditional lecture-based instruction. Instructors may need to help students understand the benefits of team-based learning and encourage their participation^{35,36}.

Team-based learning is a dynamic and effective instructional strategy that promotes active engagement, critical thinking, and collaboration among students. By integrating individual and group work, Team-based learning enhances learning outcomes and prepares students for real-world challenges. As educators seek to improve teaching methods and foster deeper understanding in subjects like Biology, implementing team-based learning can provide a transformative learning experience that not only enhances academic achievement but also develops essential skills for students' future endeavors^{34,35,36}.

2.1.4.2 Project-based Learning Strategy

Project-based learning is an instructional approach that emphasizes student-centered inquiry and active engagement through the completion of projects. This strategy encourages students to explore real-world problems and challenges, fostering a deeper understanding of content while developing critical skills such as collaboration, communication, and problem-solving. Project-based learning is grounded in real-world issues and challenges, allowing students to engage with relevant problems that affect their communities or the world. This relevance increases motivation and interest in the subject matter. In project-based learning, students take an active role in their learning process. They make decisions about their projects, including the direction of their research, the methods they will use, and how they will present their findings²⁹.

Project-based learning often involves students working in teams, fostering collaboration and teamwork. Students learn to communicate effectively, delegate tasks, and support one another, which mirrors workplace dynamics. Projects require students to engage in Inquiry-based learning, where they ask questions, conduct research, and seek answers through exploration. This process develops critical thinking and analytical skills. While the final product is important, Project-based learning emphasizes the learning process. Students reflect on their experiences, challenges, and discoveries throughout the project, leading to deeper insights. Project-based learning often integrates multiple subjects or disciplines, allowing students to make connections between different areas of knowledge. For example, a project on climate change can include science, social studies, and mathematics. Students typically present their projects to an audience, which may

include peers, teachers, community members, or experts. This public aspect adds a layer of accountability and encourages high-quality work^{28,37}.

Project-based learning increases student motivation and engagement by allowing them to explore topics they are passionate about and see the relevance of their work. Students develop essential skills such as critical thinking, problem-solving, collaboration, communication, and time management, which are crucial for success in the 21st century. The inquiry-based nature of project-based learning encourages students to delve deeper into topics, leading to a more comprehensive understanding of content and concepts. By allowing students to make choices about their projects, project-based learning fosters a sense of ownership and responsibility for their learning, increasing intrinsic motivation. Project-based learning connects classroom learning to real-world contexts, making education more relevant and preparing students for future challenges in their careers and communities^{28,29}.

Project-based learning can be time-intensive, requiring careful planning and management to ensure projects are completed within the academic schedule. Evaluating projects can be challenging due to the subjective nature of many projects. Teachers must develop clear rubrics and assessment criteria to measure student learning effectively. Some projects may require additional resources, materials, or technology, which may not always be readily available in every classroom or school. Working in teams can lead to challenges related to group dynamics, including conflicts, uneven participation, or varying levels of commitment among team members³⁷.

Project-based learning is an effective educational strategy that promotes active engagement, critical thinking, and collaboration among students. By allowing learners to

tackle real-world problems, Project-based learning fosters a deeper understanding of content while equipping students with the skills necessary for success in their academic and future professional endeavors. As educators increasingly recognize the value of Project-based learning, they can create more meaningful and impactful learning experiences for their students³⁸.

Project-based learning can also be implemented with a focus on individual student engagement rather than collaborative group work. In this context, Project-based learning emphasizes personal inquiry, independent research, and self-directed learning, allowing students to take ownership of their educational experiences. In individual-focused project-based learning, students choose topics or questions that resonate with their interests or personal experiences. This autonomy in selecting projects fosters motivation and engagement, as learners are more invested in their own inquiries. Students are responsible for managing their projects from start to finish. This includes setting goals, planning their research, gathering resources, and creating a timeline for completion. This self-directed approach encourages initiative and accountability^{37,38}.

Individual projects allow students to dive deeply into a specific topic of interest, promoting thorough understanding and mastery of content. Students engage in extensive research, critical analysis, and reflection on their findings. Students can determine how they will approach their projects, including the methods and formats they will use to present their work. This flexibility enables them to leverage their strengths and preferences, whether through writing, visual presentations, or creative mediums. Individual-focused project-based learning places a strong emphasis on self-reflection throughout the project. Students assess their progress, challenges faced, and what they

have learned about the subject matter and themselves. Each student's project is unique to their interests and learning goals, creating a personalized educational experience. This customization allows learners to connect their studies to their future aspirations or real-world issues they are passionate about. Students present their individual projects to the class or a wider audience, which serves as an opportunity to showcase their findings and articulate their learning journey. This public presentation can enhance confidence and communication skills^{39,40}.

Students gain a sense of control over their learning, which can increase motivation and commitment to their projects. The independence encourages critical thinking and decision-making skills. With the ability to focus on a topic of personal interest, students are more likely to engage in thorough exploration and develop a comprehensive understanding of the subject matter. Individual project-based learning cultivates important skills such as time management, self-discipline, and problem-solving as students navigate their projects independently. By allowing students to tailor their projects, project-based learning accommodates diverse learning styles and preferences, leading to more meaningful educational experiences. Individual-focused project-based learning encourages students to take full ownership of their educational journey, fostering intrinsic motivation and a sense of accomplishment upon project completion³⁹.

Students may face challenges in accessing resources or support, as they are working independently. This can lead to frustration if they encounter obstacles without immediate assistance. While some students thrive with autonomy, others may struggle to stay motivated or organized without the structure that collaborative projects can provide. Evaluating individual projects can be complex due to the diversity of topics and

approaches. Teachers must create clear rubrics to assess various elements such as research quality, creativity, and presentation skills. Working individually can sometimes lead to feelings of isolation. Students may miss out on the social aspects of learning that can enhance their educational experience⁴⁰.

Individual-focused project-based learning provides a valuable framework for students to engage deeply with topics of personal interest while developing essential skills for their future endeavors. By promoting autonomy, self-direction, and critical inquiry, this approach fosters a meaningful and personalized learning experience that empowers students to take charge of their educational journeys³⁸.

2.1.4.3 Traditional Teaching Strategy

Traditional teaching strategy refers to a teacher-centered instructional approach that emphasizes direct instruction, rote learning, and standardized assessments. This method typically involves the teacher as the primary source of knowledge, delivering content to students in a structured format. The teacher is the primary authority and source of information in the classroom. Instruction is delivered through lectures, demonstrations, and direct teaching methods. Lessons are often organized around a predefined curriculum with a clear sequence of topics. Content is delivered in a linear fashion, focusing on specific subject matter knowledge. Emphasis is placed on memorization and repetition. Students are often required to memorize facts, formulas, and procedures, which can lead to surface-level understanding⁴¹.

Students typically assume a passive role in the learning process, receiving information rather than actively engaging with it. Classrooms are often characterized by

limited student participation and interaction. Evaluation of student learning is commonly based on standardized tests, quizzes, and examinations. These assessments focus on recalling information rather than applying knowledge or critical thinking. Instruction often does not account for individual learning styles or differences among students. All students may be expected to learn the same material in the same way, regardless of their unique needs⁴².

The well-defined structure of traditional teaching can provide clarity and organization, helping students understand the progression of content. Teachers can cover a large amount of material in a relatively short time, making it suitable for curricula with extensive content. The predictable nature of traditional teaching can help establish a disciplined learning environment, which some students may thrive in. Traditional teaching methods often align with the format of standardized tests, providing students with the skills and knowledge needed to perform well on such assessments^{41,42}.

The passive nature of traditional teaching can lead to disengagement, as students may find lectures monotonous and uninteresting. Emphasis on memorization can result in a lack of deep understanding or critical thinking skills. Students may struggle to apply knowledge in real-world contexts. Traditional teaching often fails to accommodate diverse learning styles and paces. Students who require more time or different approaches may struggle to keep up. The focus on rote learning and standardized assessments can diminish intrinsic motivation, as students may view learning as a chore rather than an enjoyable process. Traditional teaching methods often do not encourage collaboration among students, limiting opportunities for peer learning and the development of social skills⁴³.

Traditional teaching strategies have long been a fundamental part of education systems worldwide. While they offer structure and efficiency, the limitations in student engagement, critical thinking, and individualized learning experiences have led educators to explore more interactive and student-centered approaches. Balancing traditional methods with innovative practices can enhance the learning experience and better prepare students for the complexities of the modern world⁴⁴.

Traditional teaching strategy, often referred to as the "lecture-based" or "teacher-centered" approach, is an instructional model where the teacher assumes a central role in imparting knowledge to students in a structured, systematic, and often hierarchical manner. This strategy is rooted in conventional educational methods that have been practiced for centuries, focusing on direct instruction from the teacher to the students. In a traditional classroom, the teacher typically leads the lesson, presents information, demonstrates concepts, and assigns tasks, while students assume a relatively passive role as recipients of knowledge. Though evolving educational practices have introduced a variety of teaching strategies, traditional teaching remains a dominant approach in many educational systems worldwide, especially in areas where educational reforms or resources are limited^{41,43}.

A primary characteristic of traditional teaching strategy is the lecture, where the teacher provides direct instruction on a subject by delivering content in a linear, structured format. This approach is designed to convey large amounts of information within a limited timeframe, making it an efficient way to cover the curriculum. Through lecturing, teachers have the flexibility to control the pace of the lesson, emphasizing key points, illustrating complex concepts, and guiding students through new material.

Typically, students are expected to take notes, listen attentively, and absorb the information presented. The traditional lecture model has been shown to be effective in transmitting foundational knowledge, especially in subjects that rely on factual, procedural, or historical information, such as mathematics, history, or language arts^{42,44}.

In traditional teaching, the teacher also holds authority as the main source of knowledge, guiding students' understanding of subject matter through clearly defined objectives and assessments. This role of the teacher as the "expert" or "knowledge bearer" reflects a structured hierarchy within the classroom, where students are encouraged to look up to the teacher as the primary resource for learning. The teacher, therefore, not only delivers knowledge but also monitors student progress, maintains discipline, and enforces classroom rules. This structure often promotes a sense of order and predictability, helping students to focus and follow clear, predefined expectations for academic performance and behavior⁴⁵.

Classroom management in traditional teaching strategies emphasizes control and discipline, with a strong focus on structure and order. The teacher often establishes a set of rules and routines to create a stable learning environment, aiming to minimize distractions and maximize time spent on academic tasks. This approach helps maintain a focused classroom atmosphere where students know what to expect, reducing uncertainty and fostering an environment conducive to learning. Disciplinary measures and behavioral expectations are usually communicated clearly, and adherence to these guidelines is often reinforced through rewards or penalties. Proponents argue that this level of structure helps students cultivate self-discipline, respect for authority, and a work ethic that can be beneficial in their educational journey⁴⁶.

Assessment in traditional teaching strategies generally revolves around formal methods such as tests, quizzes, and written assignments, which measure students' retention and understanding of the content covered. These assessments are often summative, given at the end of a unit or term to evaluate overall performance. The reliance on standardized tests and grades allows for a quantifiable measure of students' academic abilities, which can provide valuable data for tracking progress, making educational decisions, and reporting to parents or guardians. Although summative assessments dominate, traditional teaching may also incorporate formative assessments, such as classroom questions and homework, to monitor ongoing understanding and provide feedback. This assessment approach aligns with the traditional teaching emphasis on accountability, ensuring that students meet set academic standards^{45,47}.

Another hallmark of traditional teaching is its reliance on textbooks, workbooks, and other established curriculum resources. These materials provide a standardized, structured approach to learning that supports the sequential delivery of content. Textbooks, for example, are used as primary resources that guide the syllabus and provide consistent information across classes. This allows teachers to plan lessons based on a fixed set of materials, which can contribute to the uniformity of educational experiences across different classrooms or schools. Additionally, textbooks often include practice exercises, summaries, and review sections, which help students consolidate their understanding and prepare for assessments^{42,45}.

In the traditional teaching model, there is a high emphasis on memorization and rote learning, especially in subjects where foundational knowledge is essential. Students are often required to memorize facts, definitions, formulas, and processes to build a

strong base of knowledge. This method can be particularly effective in subjects such as mathematics and the sciences, where certain principles must be mastered before more complex concepts can be understood. While rote learning has been criticized for potentially discouraging critical thinking, it can be a valuable tool for students in acquiring fundamental knowledge quickly, particularly in educational settings where foundational skills are essential for progression⁴⁸.

Traditional teaching strategy is also commonly associated with a "one-size-fits-all" approach to instruction, where lessons are designed to address the entire class as a single unit rather than catering to individual learning styles or abilities. This standardized approach can make it challenging to accommodate students with diverse learning needs, as the teacher's primary focus is on delivering the curriculum rather than adapting it for each student. While this approach may not fully support differentiated instruction, it does provide a consistent framework within which all students are expected to learn and progress. Teachers may provide additional support for students who struggle, but the primary goal remains to follow the set curriculum in a cohesive, uniform manner^{46,48}.

Critics of traditional teaching strategies often point to its limitations in fostering creativity, problem-solving skills, and critical thinking. Since traditional teaching tends to prioritize factual knowledge and structured assessments, students may have limited opportunities to explore topics in depth, engage in hands-on activities, or apply knowledge in practical, real-world contexts. For instance, subjects like science and social studies, which benefit from experiential learning and Inquiry-based approaches, may be constrained by traditional methods that limit interactive and investigative experiences. As

a result, students may develop a passive attitude toward learning, seeing education as a process of receiving information rather than actively engaging with knowledge⁴⁹.

Despite its criticisms, traditional teaching remains a widely used strategy because it provides a stable, predictable learning environment. It is often particularly suited to large classroom settings where individualized instruction is difficult to implement. Additionally, traditional teaching can be effective in educational systems with limited resources or where the emphasis is on preparing students for standardized tests. The simplicity and clarity of this method ensure that all students receive the same foundational knowledge, supporting standardization in education and facilitating the process of assessing students' academic progress on a large scale^{43,46,48}.

Another advantage of traditional teaching strategies is that they provide a strong foundation in literacy and numeracy, which are critical for academic success. By focusing on basic skills through structured practice and repetition, traditional methods help students build competencies in reading, writing, and arithmetic that serve as the building blocks for future learning. This focus on foundational skills is particularly valuable in early education, where students require consistent, repetitive practice to master essential skills. Through traditional instruction, students develop discipline, attention to detail, and the ability to follow structured instructions, all of which contribute to academic performance^{45,48}.

In recent years, traditional teaching has evolved to incorporate elements of technology and digital resources, enhancing the delivery of content. For example, teachers may use multimedia presentations, videos, and digital whiteboards to make lectures more engaging and visually stimulating. These additions, while maintaining the

teacher-centered approach, help modernize traditional teaching by adapting it to contemporary classroom settings. Such integration of technology allows traditional teaching to remain relevant, balancing the benefits of structured instruction with the advantages of modern educational tools^{49,50}.

Ultimately, traditional teaching strategy plays a significant role in shaping educational systems worldwide, influencing how generations of students learn and acquire knowledge. It provides a framework that values consistency, structure, and academic rigor, focusing on the transmission of foundational knowledge. While it may lack the flexibility and interactivity of student-centered approaches, traditional teaching remains an effective, practical method for imparting core skills and knowledge, especially in settings where other strategies may be challenging to implement. It continues to evolve as educators find ways to integrate modern techniques and resources while preserving its foundational principles⁵⁰.

2.1.5 Gender

Gender refers to the socially constructed roles, behaviors, expressions, and identities of individuals, typically classified as masculine, feminine, or non-binary. While sex refers to biological differences (such as chromosomes, hormonal profiles, and reproductive organs), gender encompasses the roles and expectations society assigns to people based on their perceived sex. It is a complex and fluid concept, shaped by cultural, social, historical, and psychological influences. Gender is a multifaceted and socially constructed concept that influences individuals' identities, roles, and opportunities. Understanding gender beyond binary classifications allows for greater inclusivity and

helps challenge stereotypes and inequalities. In educational contexts, recognizing the impact of gender can contribute to developing strategies that promote gender equity and enhance learning outcomes for all students^{51,52}.

Gender is understood not as a fixed, innate characteristic, but as a social construct. Societies create norms and expectations around what it means to be "male" or "female," which often influence how individuals perceive themselves and how they are perceived by others. These norms can vary significantly across cultures and change over time. For example, the roles associated with being a woman in one society may be drastically different from those in another⁵³. Gender identity refers to an individual's deeply felt internal experience of gender, which may or may not align with the sex they were assigned at birth. Common gender identities include; Cisgender: When a person's gender identity matches their assigned sex at birth. Transgender: When a person's gender identity differs from their assigned sex at birth. Non-binary/Genderqueer: People who do not exclusively identify as male or female, often seeing themselves as outside or beyond the binary classification⁵⁴.

Gender roles are the expectations society places on individuals based on their perceived gender. These roles can dictate what behaviors, professions, and attributes are considered appropriate or inappropriate for people of different genders. For instance, traditionally, masculinity has been associated with traits like assertiveness, independence, and competitiveness, while femininity has been linked to nurturing, emotional expressiveness, and collaboration. Gender stereotypes are over-generalized beliefs about the characteristics and behaviors of men and women. These stereotypes can limit individuals by reinforcing rigid notions of what is acceptable for each gender. For

example, the stereotype that men are better at math and science while women are more suited for caregiving roles has historically shaped educational and career choices^{51,55}.

Gender plays a significant role in shaping educational experiences, outcomes, and future career paths. While progress has been made in addressing gender disparities in education, challenges remain. Ensuring gender equality in education requires a holistic approach that involves breaking down stereotypes, providing equitable access, and creating inclusive learning environments where students of all genders can thrive academically and personally. Efforts toward gender equality seek to eliminate disparities between genders in terms of opportunities, rights, and responsibilities. Gender equity, on the other hand, recognizes that different genders may require different resources or support to achieve equal outcomes, emphasizing fairness in treatment according to individuals' specific needs and challenges⁵⁶.

Gender and education are closely intertwined, as educational systems and practices have historically been influenced by gender norms and expectations. The interaction between gender and education can shape individuals' access to learning opportunities, their academic performance, and their future career paths. Understanding how gender influences education is crucial for addressing inequalities and promoting equity in learning environments⁵⁷.

Historically, education systems have often reflected the dominant gender norms of their societies, which has led to unequal access to education for different genders: In many parts of the world, women's access to formal education was restricted until relatively recently. Education for girls was often limited to preparing them for domestic roles, whereas boys were encouraged to pursue academic and professional careers. Men

have traditionally been expected to engage in higher education and enter professions such as law, medicine, and engineering, reflecting societal roles as breadwinners and leaders. Over the last century, global movements advocating for gender equality have expanded educational access for both girls and boys, resulting in significant progress in many countries. However, gender disparities in education persist in various forms today^{57,58}.

Although significant improvements have been made in providing educational access to both boys and girls, gender disparities still exist, particularly in developing regions. In some parts of the world, especially in rural or low-income communities, girls face greater barriers to education, including poverty, early marriage, and gender-based violence. UNESCO reports show that girls are more likely than boys to be out of school, especially in conflict zones and areas with limited educational infrastructure. In some developed regions, boys are at a higher risk of dropping out of school or underperforming academically compared to girls. Factors such as engagement with the school curriculum, societal pressures to prioritize work over education, and behavioral issues have been linked to this trend⁵⁹.

Gender disparities in academic achievement have been a subject of study for many years. Research has shown gender-based differences in performance across various subjects, often linked to societal norms and expectations. Studies show that girls tend to outperform boys in language and reading comprehension. Girls also demonstrate better classroom behavior and engagement, which can positively impact their academic success. Boys tend to perform better in areas such as mathematics and physical sciences, but this is not universal. Societal stereotypes, teacher expectations, and confidence levels have been identified as contributing factors to these patterns. However, boys may also face

challenges related to behavioral issues, classroom engagement, and motivation, which can affect their overall academic performance^{60,61,62}.

Gender, socio-economic status, and cultural expectations can significantly influence academic achievement. For instance, in many societies, gender roles and biases may affect the performance of male and female students differently, particularly in science-related subjects^{6,63,64}. In Nigeria, there is often a gender gap in science education, where male students tend to outperform females due to societal expectations, stereotypes, and limited support for girls in Science, Technology, Engineering, and Mathematics (STEM) fields. The role of parents and peers in shaping students' attitudes toward learning and academic achievement is crucial. Parental involvement in a child's education, along with a supportive peer group, can positively impact academic performance by fostering encouragement, discipline, and academic support^{60,61}.

Gender stereotypes in education are pervasive and can influence students' subject choices, academic self-concept, and career aspirations. Traditional gender stereotypes often steer girls away from subjects like Science, Technology, Engineering, and Mathematics (STEM) and encourage them toward the arts, humanities, and social sciences. Boys, on the other hand, may face pressure to excel in Science, Technology, Engineering, and Mathematics (STEM) subjects but may be discouraged from expressing interest in subjects perceived as "feminine," such as literature, art, or education. Research indicates that teachers' expectations for students' performance may differ based on gender. For example, teachers may unconsciously expect boys to be more disruptive or less focused on academics, while girls may be viewed as more diligent or obedient. These

expectations can influence how teachers interact with students, assess their abilities, and provide feedback, thus reinforcing gender disparities^{62,65}.

The school environment and peer interactions also play a significant role in reinforcing or challenging gender norms. In many classrooms, boys are more likely to dominate discussions, while girls may take on more passive roles. These dynamics can impact confidence levels, participation, and the willingness to take risks academically. Peers can also shape students' attitudes toward gender and education. Boys may experience peer pressure to conform to traditional notions of masculinity, such as downplaying academic achievement or focusing on sports. Similarly, girls may feel pressure to conform to expectations of femininity, such as avoiding "hard" subjects or excelling in social and emotional domains^{62,66}.

Promoting gender equality in education involves addressing both the visible and invisible barriers that affect students' access to and experiences in education. Ensuring that both boys and girls have equal access to education is a key priority. This involves addressing issues like school enrollment, attendance, and retention, particularly in areas where girls are more likely to drop out. A gender-sensitive curriculum recognizes and challenges gender biases in teaching materials, subjects, and learning strategies. Incorporating diverse perspectives and role models into the curriculum can help dismantle stereotypes and encourage students to pursue their interests, regardless of gender. Training teachers to be aware of gender biases and to adopt gender-inclusive teaching practices is essential for fostering an equitable classroom environment. Teachers can play a critical role in breaking down stereotypes and encouraging all students to achieve their full potential^{65,67}.

Gender norms and expectations in education often shape students' career choices. Despite efforts to encourage more girls to pursue careers in Science, Technology, Engineering, and Mathematics (STEM), these fields remain male-dominated in many countries. The underrepresentation of women in Science, Technology, Engineering, and Mathematics (STEM) is linked to factors such as gender stereotypes, lack of female role models, and a lack of encouragement from educators. Professions like nursing, teaching, and social work are often seen as “feminine” and are dominated by women. Boys may be discouraged from entering these fields due to societal expectations around masculinity^{56,65}.

2.2 Theoretical Framework

2.2.1 Constructivist Learning Theory

Constructivist Learning Theory is a psychological theory of learning that emphasizes the active construction of knowledge by learners. Developed by scholars such as Jean Piaget, Lev Vygotsky, and Jerome Bruner, Constructivist Learning Theory suggests that learners actively build their understanding of the world through experiences, interactions, and reflection. Rather than passively receiving information, learners actively construct their own knowledge by engaging with new experiences and integrating them with their existing knowledge and mental frameworks^{68,69,70}.

Constructivist Learning Theory emphasizes the importance of active engagement in the learning process. Learners are encouraged to explore, inquire, and problem-solve to make sense of new information and experiences. By actively engaging with learning materials and tasks, learners take ownership of their learning and develop a deeper understanding of the content. Based on Constructivist Learning Theory, learning involves

the construction of mental representations or schemas that organize and make sense of new information. Learners actively construct their own knowledge by integrating new information with their existing knowledge and experiences. Learning is seen as a process of meaning-making, where learners build upon their prior knowledge to construct new understandings⁷¹.

Social interaction plays a crucial role in constructivist learning environments. Collaborative learning activities, discussions, and peer interactions provide opportunities for learners to exchange ideas, negotiate meaning, and co-construct knowledge together. Social interactions with peers, teachers, and experts contribute to the development of learners' understanding and perspective-taking abilities. Constructivist Learning Theory emphasizes the importance of providing scaffolding and support to learners as they engage in challenging tasks. Scaffolding refers to the support and guidance provided by more knowledgeable individuals to help learners reach higher levels of understanding and competence. The Zone of Proximal Development (ZPD) represents the gap between what learners can do independently and what they can achieve with the support of others. By providing appropriate scaffolding, educators can support learners' progress within their ZPD and facilitate their learning⁶⁸.

Constructivist approaches encourage learners to engage in reflection and metacognition, or thinking about their own thinking. Reflection involves actively reviewing and evaluating one's own learning experiences, identifying areas of understanding and areas for improvement, and setting goals for future learning. Metacognition involves awareness and control of one's own cognitive processes, including planning, monitoring, and evaluating learning strategies. Constructivist

Learning Theory advocates for learning experiences that are situated in authentic, real-world contexts. Authentic tasks and problems provide meaningful and relevant contexts for learning, allowing learners to apply their knowledge and skills to solve authentic problems and address real-world challenges. Authentic learning experiences promote deeper understanding and transfer of learning to new situations⁷².

Constructivist Learning Theory has profound implications for teaching and learning practices. Educators who embrace constructivist principles design learning environments that are student-centered, inquiry-driven, and collaborative. They create opportunities for active engagement, social interaction, and reflection, fostering deep understanding and lifelong learning skills in their students. By aligning instruction with constructivist principles, educators can empower learners to become active agents in their own learning journey⁷³.

Active engagement in learning refers to the active involvement of learners in the learning process. Instead of passively receiving information, learners are actively participating, interacting, and contributing to their own learning experiences. Active engagement fosters deeper understanding, retention, and transfer of knowledge by encouraging learners to think critically, apply concepts in different contexts, and make connections between new information and their existing knowledge^{72,73}.

Engaging learners in hands-on activities, experiments, simulations, or practical tasks allows them to actively manipulate materials, explore concepts, and experience learning firsthand. Hands-on activities promote active engagement by providing opportunities for sensory experiences, problem-solving, and skill development. Encouraging learners to ask questions, pose hypotheses, and explore answers through

Inquiry-based learning promotes active engagement and curiosity. Inquiry-based approaches challenge learners to think critically, analyze evidence, and construct explanations, fostering a deeper understanding of the subject matter⁷³.

Collaborative learning activities, such as group discussions, peer teaching, or collaborative projects, promote active engagement by encouraging learners to interact with peers, share ideas, and negotiate meaning together. Collaborative learning fosters social interaction, communication skills, and teamwork while promoting deeper understanding through peer interaction and collective problem-solving. Presenting learners with real-world problems, challenges, or case studies encourages active engagement by requiring them to apply their knowledge and skills to solve authentic problems. Problem-solving tasks stimulate critical thinking, creativity, and metacognitive skills as learners analyze situations, generate solutions, and evaluate their effectiveness⁷⁴.

Engaging learners in active participation during class discussions, debates, or Socratic seminars encourages them to express their ideas, share perspectives, and engage in dialogue with peers. Active participation promotes critical thinking, communication skills, and deeper understanding as learners articulate their thoughts, justify their reasoning, and respond to alternative viewpoints. Incorporating interactive technology tools, such as multimedia presentations, educational games, or online simulations, can enhance active engagement by providing interactive and immersive learning experiences. Interactive technology tools allow learners to explore concepts, manipulate variables, and receive immediate feedback, promoting active experimentation and exploration^{73,74}.

Encouraging learners to engage in reflection and metacognition promotes active engagement by fostering awareness of one's own thinking processes and learning

strategies. Reflection involves reviewing and evaluating learning experiences, identifying areas of understanding and areas for improvement, and setting goals for future learning. Metacognition involves monitoring, regulating, and adapting one's own learning strategies to optimize learning outcomes. Overall, active engagement in learning is essential for promoting deeper understanding, retention, and transfer of knowledge. By providing opportunities for hands-on activities, Inquiry-based learning, collaborative interaction, problem-solving tasks, active participation, interactive technology tools, and reflection, educators can foster a dynamic and engaging learning environment that empowers learners to become active participants in their own learning journey⁷⁵.

Knowledge construction refers to the process by which learners actively build their understanding of the world through experiences, interactions, and reflection. Instead of passively receiving information, learners actively engage in cognitive processes to make sense of new information and integrate it with their existing knowledge and mental frameworks. Knowledge construction is a central concept in constructivist theories of learning, which emphasize the active role of learners in creating their own knowledge and understanding. Knowledge construction involves active engagement in the learning process. Learners participate in activities, experiences, and interactions that require them to think critically, analyze information, and apply concepts in different contexts. Active engagement promotes deeper understanding and retention of knowledge by encouraging learners to actively process and integrate new information with their existing knowledge^{72,76}.

Learners construct mental models or cognitive structures that represent their understanding of the world. These mental models organize knowledge, concepts, and

relationships into coherent frameworks that help learners make sense of their experiences and guide their behavior. Through experiences, interactions, and reflection, learners refine and revise their mental models to accommodate new information and perspectives. Knowledge construction involves making connections between new information and existing knowledge. Learners actively seek out connections, patterns, and relationships between concepts, drawing upon their prior knowledge to make sense of new experiences. By making connections, learners deepen their understanding and develop a more integrated and interconnected network of knowledge. Knowledge construction is a process of meaning-making, where learners actively interpret, analyze, and evaluate information to construct meaning and understanding. Learners engage in sense-making activities, such as asking questions, seeking explanations, and synthesizing information, to construct coherent and meaningful interpretations of the world around them⁷⁷.

Social interactions support knowledge construction by exposing learners to diverse perspectives, challenging their assumptions, and promoting deeper understanding through dialogue and debate. Knowledge construction involves reflection and metacognition, or thinking about one's own thinking. Learners engage in metacognitive processes, such as monitoring, evaluating, and regulating their own learning, to make sense of their experiences and improve their understanding. Reflection allows learners to review and evaluate their thinking processes, identify areas of understanding and areas for improvement, and set goals for future learning. Knowledge construction is a dynamic and iterative process that involves active engagement, making connections, meaning-making, social interaction, and reflection. By empowering learners to construct their own

knowledge through experiences, interactions, and reflection, educators can foster deeper understanding, critical thinking, and lifelong learning skills^{68,78}.

Social interaction in the context of learning refers to the exchange of ideas, perspectives, and experiences between learners, teachers, and peers. It plays a crucial role in the learning process by providing opportunities for collaboration, communication, and cooperative learning. Social interaction enhances learning outcomes by promoting deeper understanding, critical thinking, and knowledge construction through dialogue, negotiation, and shared experiences. Social interaction facilitates collaborative learning, where learners work together to achieve shared learning goals. Collaborative learning activities, such as group discussions, cooperative projects, and peer teaching, provide opportunities for learners to engage in joint problem-solving, share expertise, and co-construct knowledge together. Collaborative learning promotes active engagement, deeper understanding, and the development of teamwork and communication skills^{68,70,78}.

Peer interaction allows learners to exchange ideas, perspectives, and feedback with their peers. Peer discussions, debates, and peer review activities provide opportunities for learners to challenge their assumptions, consider alternative viewpoints, and refine their understanding through dialogue and debate. Peer interaction fosters a sense of community, mutual support, and collective learning among learners. Social interaction is central to social constructivist theories of learning, which emphasize the role of social interaction in knowledge construction. Based on social constructivist learning theory, learning is a social process that occurs through interaction with others in meaningful contexts. Learners actively construct their understanding of the world through dialogue, collaboration, and shared experiences with peers and teachers^{77,78}.

Social interaction provides opportunities for scaffolding, where more knowledgeable individuals (such as teachers or peers) provide support and guidance to learners as they engage in challenging tasks. Scaffolding helps learners progress within their Zone of Proximal Development (ZPD), the gap between what learners can do independently and what they can achieve with the support of others. By providing appropriate scaffolding, educators can support learners' learning and development in a social context. Social interaction allows learners to engage with diverse perspectives, cultural backgrounds, and experiences. Interacting with peers from different cultural backgrounds promotes cultural awareness, empathy, and appreciation for diversity. By engaging in dialogue and collaboration with peers from diverse backgrounds, learners develop intercultural competence and broaden their understanding of the world^{78,79}.

Social interaction provides opportunities for learners to receive feedback, reflect on their learning, and revise their understanding based on input from others. Peer feedback, teacher feedback, and collaborative reflection promote metacognitive awareness and self-regulated learning. By engaging in dialogue and reflection with peers and teachers, learners deepen their understanding, identify areas for improvement, and set goals for further learning. Social interaction plays a vital role in the learning process by promoting collaboration, communication, and knowledge construction. By fostering a supportive and interactive learning environment that encourages social interaction, educators can enhance learning outcomes, promote critical thinking, and foster a sense of community among learners^{68,79}.

Scaffolding and the Zone of Proximal Development (ZPD) are key concepts in educational psychology, particularly associated with the work of Lev Vygotsky. They

describe how learners can be supported in their learning process to reach higher levels of understanding and competence. The Zone of Proximal Development (ZPD) refers to the gap between what a learner can do independently and what they can achieve with the guidance and support of a more knowledgeable individual, such as a teacher, peer, or mentor. The ZPD represents the range of tasks or activities that are too difficult for the learner to accomplish alone but can be accomplished with guidance and support. It is the "sweet spot" where learning is maximized. Vygotsky emphasized that learning should occur within the ZPD, as it promotes cognitive development and allows learners to advance to higher levels of understanding and competence⁶⁸.

Scaffolding is the process of providing temporary support, guidance, or assistance to learners as they engage in challenging tasks or activities within their ZPD. The term "scaffolding" comes from the analogy of a scaffold in construction, which provides temporary support to workers as they build a structure. Similarly, scaffolding in education provides support to learners as they construct their understanding. Scaffolding can take various forms, including modeling, questioning, providing cues or hints, breaking tasks into smaller steps, offering feedback, and adjusting the level of support based on learners' needs. The goal of scaffolding is to gradually reduce support as learners gain competence and move toward independent mastery of the task or concept. The ultimate aim is for learners to internalize the skills and strategies they have learned and become more self-regulated learners. In summary, the ZPD represents the range of tasks that are just beyond a learner's current level of independent ability, while scaffolding refers to the support provided to help learners successfully complete tasks within their ZPD. Together, scaffolding and the ZPD provide a framework for

understanding how learners can be supported in their learning process to achieve optimal cognitive development and academic success⁶⁸.

Reflection and metacognition are cognitive processes that involve thinking about one's own thinking, learning, and problem-solving strategies. They play crucial roles in the learning process by promoting self-awareness, self-regulation, and deeper understanding. Both reflection and metacognition help learners monitor, evaluate, and adapt their learning strategies to optimize learning outcomes and achieve academic success. Reflection involves actively reviewing and evaluating one's own learning experiences, thoughts, and actions. It includes thinking critically about what was learned, how it was learned, and why it was learned. Reflection prompts learners to consider the significance of their learning experiences, identify areas of understanding and areas for improvement, and make connections between new information and prior knowledge. Reflective activities can take various forms, including journaling, self-assessment, think-aloud, and structured reflection prompts. These activities encourage learners to engage in metacognitive processes and deepen their understanding through self-examination and self-analysis^{68,77}.

Metacognition refers to awareness and control of one's own cognitive processes, including planning, monitoring, and evaluating learning strategies. It involves thinking about how one learns, what strategies are effective, and when adjustments are needed. Metacognitive skills enable learners to regulate their learning behaviors, set goals, monitor their progress, and adapt their strategies based on feedback and self-assessment. Metacognition is essential for self-regulated learning, which refers to learners' ability to

take control of their learning process and manage their own learning activities effectively⁷⁷.

Together, reflection and metacognition promote deeper understanding, critical thinking, and lifelong learning skills by empowering learners to take an active role in their learning process. By engaging in reflection and metacognition, learners develop a greater awareness of their strengths and weaknesses, become more strategic and effective learners, and take ownership of their learning journey. Educators can support the development of reflection and metacognition by incorporating opportunities for self-reflection, self-assessment, and metacognitive instruction into their teaching practices. By fostering a culture of reflection and metacognition in the classroom, educators can empower learners to become more autonomous, self-directed, and lifelong learners⁶⁸.

Authentic learning contexts refer to real-world or real-life situations that provide meaningful and relevant contexts for learning. In authentic learning, learners engage in tasks, activities, and projects that mirror or simulate authentic, real-world experiences, problems, or challenges. Authentic learning contexts promote deeper understanding, transfer of learning, and application of knowledge and skills to real-life situations. Authentic learning contexts are meaningful and relevant to learners' lives, interests, and experiences. They connect classroom learning to real-world contexts and everyday experiences, making the learning process more engaging, meaningful, and personally relevant for learners. Authentic learning contexts involve tasks, activities, or projects that reflect real-world problems, challenges, or situations. Learners engage in problem-solving, critical thinking, and decision-making to address authentic problems and develop solutions that have real-world applications⁷¹.

Authentic learning contexts are characterized by complexity, ambiguity, and authenticity. They present learners with situations that are multifaceted, open-ended, and reflective of the complexities of the real world. Learners grapple with real-world constraints, uncertainties, and ethical considerations as they work towards solutions. Authentic learning contexts often integrate multiple disciplines, perspectives, and domains of knowledge. They provide opportunities for learners to make interdisciplinary connections, draw upon diverse areas of knowledge, and apply skills and concepts from various disciplines to address complex, real-world problems. Authentic learning contexts emphasize the application of knowledge and skills to real-life situations. Learners engage in hands-on activities, projects, or simulations that require them to apply concepts, principles, and procedures in authentic contexts, promoting deeper understanding and transfer of learning. Authentic learning contexts often involve collaboration with community partners, experts, or stakeholders. Learners work collaboratively with peers, mentors, or external partners to address real-world problems, share expertise, and contribute to meaningful outcomes that have an impact beyond the classroom^{71,72}.

Examples of authentic learning contexts include: Designing and implementing a community service project to address a local need or issue; Conducting scientific investigations or experiments that address real-world phenomena or problems; Participating in simulations or role-playing activities that simulate real-world scenarios, such as business negotiations or historical events; Engaging in Project-based learning experiences that involve interdisciplinary inquiry, research, and problem-solving to address authentic challenges. Overall, authentic learning contexts provide rich and immersive learning experiences that promote deeper understanding, critical thinking, and

transfer of learning to real-world situations. By connecting classroom learning to authentic contexts, educators can foster engagement, relevance, and meaningful learning outcomes for learners^{72,76}.

Piaget's theory of cognitive development laid the groundwork for Constructivist Learning Theory. He proposed that children progress through stages of development, actively constructing knowledge as they interact with their environment. His concepts of assimilation (integrating new experiences into existing frameworks) and accommodation (modifying existing frameworks to incorporate new experiences) are fundamental to constructivist learning. Vygotsky emphasized the social and cultural aspects of learning. He introduced the concept of the Zone of Proximal Development (ZPD), which refers to the difference between what a learner can do independently and what they can achieve with guidance from a more knowledgeable person. Vygotsky argued that social interaction is crucial for cognitive development. Bruner emphasized the importance of discovery learning, where students learn best by discovering facts and relationships for themselves. He advocated for teaching strategies that encourage exploration, inquiry, and problem-solving⁶⁹.

Educators should create opportunities for students to work together in groups, share ideas, and engage in discussions. Group work and peer teaching can foster deeper understanding and critical thinking. Teachers should design lessons that encourage students to ask questions, explore topics of interest, and conduct investigations. This approach nurtures curiosity and a desire for lifelong learning. Recognizing that students have diverse backgrounds and learning styles, educators should adapt their teaching methods to meet individual needs. This can involve varying tasks, resources, and

assessment methods to support all learners. Assessment should include tasks that reflect real-world challenges and allow students to demonstrate their understanding in meaningful ways. This may involve portfolios, presentations, or projects that assess both the process and product of learning. Teachers act as facilitators rather than traditional sources of knowledge. They guide discussions, provide resources, and support students in their learning journey, allowing students to take charge of their educational experiences^{69,71}.

Constructivist learning theory provides a comprehensive framework for understanding how students learn and develop knowledge. By emphasizing active engagement, social interaction, and the importance of prior knowledge, Constructivist Learning Theory encourages a more dynamic and meaningful approach to education. The principles of Constructivist Learning Theory have significant implications for teaching strategies, curriculum design, and assessment, promoting a learning environment that nurtures critical thinking, collaboration, and lifelong learning^{80,81}.

Team-based Learning is an instructional strategy that promotes collaborative learning and critical thinking through structured team activities. The integration of constructivist principles in Team-based Learning creates a rich learning environment that enhances student engagement and understanding. Students complete assigned readings or learning materials before class. This preparation allows them to come to class with a foundation of knowledge. By encouraging students to review materials beforehand, Team-based Learning acknowledges and builds on students' prior knowledge. Students engage with the content actively and prepare for collaborative learning in the classroom^{33,71}.

Students take a short quiz individually to assess their understanding of the pre-class materials. The individual Readiness Assurance Test (iRAT) encourages students to reflect on their understanding and identify gaps in knowledge. This self-assessment aligns with the constructivist principle of self-directed learning. After the individual test, students retake the same quiz in their teams, discussing answers and rationales. The team Readiness Assurance Test (tRAT) fosters social interaction and collaboration, allowing students to learn from one another. This process embodies the constructivist view that knowledge is co-constructed through dialogue and shared understanding^{34,71}.

Teams work on complex, real-world problems or case studies that require critical thinking and application of concepts. These activities provide a meaningful context for learning, where students apply their knowledge to solve practical problems. This aligns with the constructivist principle that learning is most effective in relevant, authentic situations. After completing activities, teams receive feedback from peers and instructors, and students reflect on their learning experiences. Feedback promotes reflection and deeper understanding, allowing students to evaluate their learning processes. This aligns with the constructivist emphasis on reflection as a vital component of learning. Instructors guide discussions, provide resources, and support teams in their learning journey. The instructor acts as a facilitator rather than a traditional source of knowledge. This role encourages students to take ownership of their learning, consistent with constructivist principles^{34,74}.

Team-based Learning fosters active participation and engagement, making learning more meaningful and enjoyable for students. The emphasis on problem-solving and application of knowledge encourages students to think critically and analytically.

Working in teams helps students develop essential collaboration and communication skills, preparing them for real-world scenarios. Engaging with peers and actively applying concepts enhances retention and understanding of ecological principles. Team-based Learning promotes a sense of community and support among students, which can enhance motivation and confidence³⁵.

The integration of constructivist learning theory into Team-based Learning creates a powerful educational framework that enhances student learning and engagement. By emphasizing active participation, collaboration, and reflection, Team-based Learning aligns with constructivist principles and provides students with meaningful opportunities to construct their understanding of ecological concepts. This approach not only deepens knowledge but also prepares students for lifelong learning and teamwork in diverse settings^{34,71,74}.

Project-based Learning is an instructional strategy that engages students in exploring real-world problems and challenges through extended projects. When aligned with constructivist learning theory, Project-based Learning emphasizes the learner's active role in the learning process, facilitating knowledge construction through personal exploration and individual inquiry. This approach allows students to take ownership of their learning while connecting new concepts to their prior knowledge and experiences³⁹.

Projects are centered around complex, authentic issues or questions that are relevant to students' lives and interests. This relevance helps students connect new knowledge to their existing understanding, promoting engagement and motivation. Students select specific aspects of the project that interest them, allowing for personalized learning paths. This approach respects individual differences and promotes self-directed

learning, enabling students to construct knowledge based on their interests and experiences. Students conduct research, gather information, and investigate various sources to develop their understanding of the topic. The emphasis on inquiry supports the constructivist principle that knowledge is constructed through exploration and engagement with diverse perspectives and resources^{39,80}.

Students apply their knowledge and skills to create solutions, products, or presentations that address the project question or problem. Engaging in problem-solving fosters critical thinking and allows students to actively construct and test their understanding of concepts, aligning with constructivist views on learning. Throughout the project, students are encouraged to reflect on their learning processes, challenges, and successes. Reflection is crucial for consolidating learning, allowing students to evaluate their understanding and adjust their approaches as necessary, consistent with constructivist principles. At the project's conclusion, students present their findings and solutions to peers, teachers, or a broader audience. Sharing knowledge reinforces learning and encourages dialogue, enabling students to articulate their understanding and receive feedback, further deepening their comprehension^{40,81}.

Benefits of applying constructivist learning theory in individual-focused project-based learning: Students have the autonomy to pursue topics that resonate with them, making learning more meaningful and relevant. The process of researching, analyzing, and solving problems encourages students to think critically and creatively, fostering higher-order thinking skills. Individual exploration empowers students to take charge of their learning journey, promoting motivation and a sense of agency. Engaging in self-directed inquiry allows students to connect new knowledge with their existing

frameworks, resulting in a more profound and integrated understanding of the subject matter. The emphasis on inquiry and presentation enhances students' abilities to gather information, analyze data, and communicate their findings effectively. The skills developed through Project-based learning; such as self-directed learning, critical thinking, and effective communication are essential for success in future academic and professional endeavors^{39,40,81}.

The application of constructivist learning theory in Project-based Learning with an individuality approach creates a rich learning environment that emphasizes personal exploration, ownership, and critical thinking. By allowing students to engage with real-world problems through self-directed inquiry, educators foster a deeper understanding of concepts and prepare students for lifelong learning. This alignment not only enhances academic achievement but also equips students with essential skills for success beyond the classroom^{39,71}.

2.3 Review of the Empirical Studies

2.3.1 Team-based Learning Strategy and Academic Achievement in Ecology

Team-based Learning (TBL) is an effective pedagogical strategy that promotes student engagement, accountability, and equity in both face-to-face and online classrooms. Rooted in evidence-based educational theories, TBL incorporates active learning methods such as self-testing, team discussions, and the application of knowledge, all of which contribute to better student performance, retention, and a stronger sense of

belonging; factors that are often lacking in online courses. In this study, Team-based Learning was implemented in both a face-to-face introductory course on evolution and biodiversity with approximately 200 students (starting in 2018) and an online version of the same course with around 30 students (starting in the summer of 2019). To facilitate the transition to an online environment, various online tools and applications were used, including Simbio, Slack, Voice Thread, Articulate 360, and Teammates⁸².

The results from the online implementation of team-based learning were positive; students were engaged and accountable for their learning, leading to strong performance throughout the course. The success of this model serves as an example of how to design a life science course using Team-based Learning principles and transition it effectively to an online platform. Given the increasing shift toward remote instruction and online learning, the study recommends adopting team-based learning as a course design approach that can significantly enhance the online learning experience for students⁸².

This study aimed to explore the impact of two different teaching strategies; jigsaw learning teams and teacher-led discussion on secondary school students' performance in Ecology. The issue of poor performance in Biology has often been attributed to factors such as large class sizes, challenging concepts, and the teachers' presentation skills. To address this, the study sought to determine the effectiveness of these two teaching methods in enhancing students' academic performance. The research used a quasi-experimental, non-randomized pretest-posttest design. A total of eighty Senior Secondary One (SS1) students from two intact classes in a public secondary school in Ikwuano Local Government Area, Abia State, were selected through a multi-stage random

sampling technique. Data were collected using a twenty-item Ecology Attainment Test, which had a Kuder-Richardson reliability coefficient of 0.78⁸³.

The findings showed that students who were taught Ecology through the Jigsaw learning teams' strategy performed better in the Ecology Attainment Test compared to those taught using the Teacher-Led Discussion strategy. However, this difference in performance was not statistically significant. The study recommends that Biology teachers should vary their instructional strategies to offer students diverse learning opportunities and enable them to take responsibility for their learning. It also suggests adopting interactive and collaborative teaching methods, such as Jigsaw learning, to create a learning environment where students can explain concepts to each other, fostering greater engagement and understanding. By implementing a variety of teaching strategies, teachers can improve students' performance in Biology, particularly in complex topics like Ecology⁸³.

This study aimed to compare the effectiveness of the cooperative learning approach versus conventional teaching methods in enhancing students' academic achievement and attitudes towards Biology. Recognizing that the quality of education largely depends on how teachers interact with students in the classroom, the study focused on determining whether the cooperative learning approach could yield better results than traditional direct Instruction. The research employed an experimental design and used a researcher-made achievement test and an attitude survey to measure the outcomes. The experimental group was taught using the cooperative learning approach, while the control group received instruction through direct instruction. The results showed that the experimental group demonstrated a 41.86% improvement in their pre-

and post-achievement test scores, compared to the 36.49% improvement in the control group. Similarly, the experimental group showed a greater improvement of 81.90% in their attitude survey, while the control group achieved 81.69% improvement⁸⁴.

Despite these improvements, t-tests and F-tests conducted to analyze the data revealed that there were no significant differences between the pre- and post-test scores in both the achievement tests and attitude surveys at the 0.05 probability level. This suggests that while the cooperative learning approach resulted in positive gains, the differences between the two teaching methods were not statistically significant. In conclusion, although the cooperative learning approach showed some advantages in improving students' performance and attitudes, the study indicated that these improvements were not significant when compared to Direct Instruction. Therefore, while cooperative learning has potential benefits, further research is needed to explore its effectiveness more deeply⁸⁴.

This meta-analysis aimed to examine the impact of group work as an active learning strategy on student performance in biology classrooms. The analysis included data from 91 studies drawn from 53 articles. The overall findings revealed that the implementation of group work in biology classrooms resulted in an improvement of 1.00 standard deviation in student performance, which translates to a change greater than one letter grade. Further analysis of the data showed that this positive impact held true across a variety of conditions, including different group sizes, class sizes, and for both biology and life science majors as well as non-majors. Additionally, the performance boost was consistent regardless of whether the groups were assigned by the instructor⁸⁵.

However, the study found that group work did not significantly improve performance in graduate-level courses or in cases where group work was incorporated for only part of the course term (e.g., less than a semester or quarter). Furthermore, when group work was not graded, no performance improvement was observed. These results underscore the effectiveness of group work in enhancing student performance in biology and highlight the importance of studying specific active learning strategies to understand their full potential. The findings suggest that group work, when implemented effectively, can lead to significant academic improvements⁸⁵.

This study sought to examine the effectiveness of Computer-Supported Collaborative Learning (CSCL) on academic achievement by conducting a meta-analysis of existing research. The goal was to aggregate findings from various studies to determine the overall impact of computer-supported collaborative learning interventions on students' academic performance. To achieve this, the research team analyzed a total of 40 studies that were carried out between 2010 and 2020. These studies met specific inclusion criteria, which ensured that only relevant and high-quality research was considered. The total sample of participants across all included studies amounted to 3,474 students. The data from these studies were processed using Comprehensive Meta-Analysis (CMA) software to calculate the effect size and combined effect size for each study. The effect size is a statistical measure that quantifies the strength of the relationship between computer-supported collaborative learning and academic achievement, while the combined effect size provides an overall estimate based on the aggregation of individual study results⁸⁶.

From the analysis, it was found that the majority of the studies were conducted at the university level. These studies typically involved medium sample sizes and were published in academic articles. Most of the research focused on disciplines within the sciences and social sciences, indicating a concentrated interest in the impact of computer-supported collaborative learning within these fields. In terms of the intervention durations, a significant portion of the studies (37.8%) were carried out with intervention periods ranging between 1 and 4 weeks, suggesting that many researchers opted for relatively short-term computer-supported collaborative learning interventions in their investigations⁸⁶.

The overall effect size calculated across all studies was found to be 0.523, which is considered a moderate effect. This suggests that computer-supported collaborative learning has a positive impact on students' academic achievement, though the effect is not overwhelmingly large. The moderate effect size indicates that CSCL strategies contribute to academic success, but there are other factors at play that can influence the outcomes, such as the quality of implementation, the subject matter, and the learning environment. In addition to calculating the overall effect size, the researchers conducted a moderator analysis to investigate whether specific factors influenced the effectiveness of computer-supported collaborative learning. The analysis revealed that the learning stage, subject domain, and sample size did not significantly alter the effectiveness of computer-supported collaborative learning on academic achievement. This suggests that computer-supported collaborative learning has a broadly applicable impact across different educational contexts, regardless of whether the intervention is used in primary, secondary, or higher education, or whether the subject matter is scientific, social, or otherwise⁸⁶.

However, the moderator analysis did indicate that the duration of the intervention played a role in determining the effectiveness of computer-supported collaborative learning. Studies that implemented computer-supported collaborative learning for longer periods showed stronger positive effects on academic achievement compared to shorter interventions. This finding suggests that for computer-supported collaborative learning to be most effective, it may require more sustained engagement from students and instructors to fully realize its potential benefits⁸⁶.

In conclusion, the meta-analysis found that Computer-Supported Collaborative Learning (CSCL) has a moderate positive effect on academic achievement across various educational settings. The analysis also highlighted the importance of intervention duration in maximizing the effectiveness of computer-supported collaborative learning. Based on these findings, the study recommends that educators and researchers consider longer computer-supported collaborative learning interventions to improve academic performance, as the duration of engagement appears to play a key role in the success of the strategy. Additionally, the findings suggest that computer-supported collaborative learning can be a beneficial teaching strategy across diverse disciplines and educational levels, offering a flexible and impactful approach to enhancing student learning⁸⁶.

2.3.2 Project-based Learning Strategy and Academic Achievement in Ecology

This study focused on developing a learning model that integrates Project-based Learning (PBL) with the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach to enhance science literacy among students. The primary aim was to create a teaching framework that aligns with the demands of 21st-century learning, focusing on improving students' science literacy while considering their individual

characteristics and expected learning outcomes. The research followed several stages: starting with a needs analysis, then proceeding to product design, product development, product implementation, and ultimately, evaluation. The study involved 35 grade X students from SMAN 2 Selong, including 25 female and 10 male students. The instruments for data collection included a variety of guidelines: a needs analysis questionnaire, product validation criteria, practicality assessment guidelines, teacher response forms, and learning outcome tests specifically designed for the topic of ecosystem materials⁸⁷.

The data collected was analyzed descriptively, revealing key findings: Product Validity: The learning model was deemed valid, receiving positive evaluations from three experts in the fields of linguistics, material science, and learning technology. The average scores from these experts were 83.91, 84.64, and 83.73, respectively, confirming that the model met academic and practical standards. Product Practicality: The model was also evaluated as practical, with an average score of 82.63, suggesting that it could be effectively implemented in the classroom setting. Product Effectiveness: The model was found to be effective, with an effectiveness percentage of 88.57%, indicating its success in improving student learning in the ecosystem subject. Improvement in Learning Outcomes: The intervention led to a significant improvement in student performance, as shown by an N-Gain score of 0.76, which reflects the model's effectiveness in enhancing students' understanding of the taught content⁸⁷.

Overall, the study demonstrated that integrating Project-based Learning (PBL) with the STEAM approach has great potential in improving science literacy and achieving better learning outcomes. The model was valid, practical, and effective, and its

use significantly boosted students' knowledge of ecosystem topics. This approach offers a promising way to prepare students with the skills needed for 21st-century challenges and provides a deeper, more engaging learning experience in science⁸⁷.

The study explored the impact of the Field Trip Teaching Strategy (FTIS) on the academic achievement of Senior Secondary One (SS1) students in ecology within Anambra State. It aimed to determine whether field trips enhance students' understanding of ecological concepts more effectively than the Conventional Lecture Method (CLM). To achieve this, the research was guided by two research questions, and three hypotheses were tested at a 0.05 alpha level. A quasi-experimental design, specifically a non-randomized control group design, was adopted. The study employed a multistage sampling technique to select 148 SS1 students from 33 co-educational schools in the Nnewi Education Zone, drawn from a total population of 20,536 students. Two intact classes were randomly assigned to the experimental group, which was taught ecology through field trips, and the control group, which received instruction using the conventional lecture method. To assess students' performance, a validated Biology Achievement Test (BAT) was used, with a reliability estimate of 0.89. The collected data were analyzed using mean and standard deviation to answer the research questions, while Analysis of Covariance (ANCOVA) was used to test the hypotheses².

The findings revealed that students who participated in field trips performed significantly better in ecology compared to those who were taught using traditional lecture methods. This suggests that field trips provide students with a more engaging and immersive learning experience, allowing them to directly observe and interact with ecological concepts. Additionally, the study found that gender had no significant effect

on students' achievement, indicating that both male and female students benefited equally from the field trip experience².

Based on these findings, the study recommends that curriculum planners should integrate field trips into the SS1 Biology curriculum to provide students with practical, hands-on learning opportunities. Teachers are also encouraged to adopt field trips as a teaching strategy to enhance students' engagement and comprehension of ecological concepts. Furthermore, schools and educational authorities should offer the necessary support to facilitate field trips, ensuring that students gain firsthand experiences that reinforce classroom learning. Ultimately, this study highlights the value of experiential learning in improving students' understanding and retention of biological concepts, particularly in ecology. By incorporating field trips into the teaching process, educators can create a more interactive and enriching learning environment that fosters deeper knowledge and appreciation of the natural world².

Problem-solving is the process of developing solutions to overcome obstacles and achieve a desired goal. However, in the context of 21st-century learning, problem-solving skills go beyond simply finding answers to specific problems. Students must be able to express opinions, support their arguments with evidence, and apply biological knowledge to real-life situations. To achieve this, Project-based Learning (PBL) must incorporate the 4C elements; Communication, Collaboration, Critical Thinking, and Creativity to enhance students' problem-solving abilities. An analytical study was conducted with seven students involved in Project-based Learning, using observation, document analysis, and interviews to identify challenges in the learning process. The second phase of the study aimed to test an initial theory using the ISP Model through similar data collection

methods. The third phase focused on refining findings or theories by conducting further interviews, observations, and document analysis⁸⁸.

This research, designed as a qualitative case study, seeks to provide deeper insights into the application of 4C elements in online project-based learning for Biology. The collected data were analyzed using the triangulation technique, ensuring accuracy and reliability. The findings highlight the importance of integrating 4C elements into project-based learning, particularly in an online setting, to improve students' problem-solving skills. This concept paper presents a framework for implementing 4C elements in project-based learning through modeling, guidance, and strategic application. Project-based Learning is an instructional method that prioritizes hands-on projects, cooperative learning, and inquiry-based exploration, allowing students to actively build knowledge and skills. By incorporating structured strategies into project-based learning, students can develop the necessary skills to approach and solve complex biological problems effectively⁸⁸.

The academic performance of students is a global concern for educators, as it directly influences learning outcomes and future opportunities. This study investigated the effect of STEM Problem-based Learning (STEM-PBL) as an inquiry-based approach on the performance of secondary school students in Biology at government-owned secondary schools in Kebbi State, Nigeria. A non-equivalent control group design was employed, with two schools selected for the study. Purposive sampling was used to choose participants, and each class consisted of 40 students. Data were collected using the Diffusion and Osmosis Achievement Test (DOAT), and the results were analyzed using descriptive statistics and the Independent Samples t-test⁸⁹.

Findings revealed that STEM Problem-based Learning had a significant and positive impact on students' achievement in Biology. Students in the experimental group, who were taught using STEM Problem-based Learning, retained more Biology concepts compared to those in the control group, who were taught using traditional methods. Based on these findings, the study recommends that Biology lessons should be made more engaging to enhance student participation and learning. Teachers should also adopt creative and innovative instructional strategies, particularly activity-based methods, to improve students' understanding and retention of biological concepts. This research highlights the importance of inquiry-based learning approaches like STEM Problem-based Learning in fostering deeper comprehension and long-term retention of scientific knowledge among students. By integrating such strategies into classroom instruction, educators can create a more stimulating and effective learning environment⁸⁹.

This study explored the impact of Problem-based Learning (PBL) on the academic achievement of Science Education students in Ecology Concepts in Gusau. Given the growing need for effective teaching strategies in science education, the study aimed to determine whether Problem-based Learning could enhance students' understanding and retention of ecological concepts compared to conventional teaching methods. A quasi-experimental pretest-posttest control group design was employed. The study population consisted of 1,225 Senior Secondary Two (SS2) Biology students from 11 public secondary schools in Zaria Metropolis. From this population, a random sample of 137 students from two schools was selected. The students were divided into two groups: an experimental group, which was taught Ecology using Problem-based Learning, and a control group, which received instruction through traditional teaching methods⁹⁰.

To assess students' performance, the Ecology Achievement Test (EAT) was used as the primary data collection instrument. The test was validated and had a reliability coefficient of 0.87, established through Pearson Product Moment Correlation. The research was guided by two research questions and two null hypotheses, which were analyzed using Mean, Standard Deviation, and Independent Samples t-test at a 0.05 level of significance. The findings revealed that students who were taught using Problem-based Learning performed significantly better than those taught through conventional methods. This suggests that Problem-based Learning encourages deeper engagement, critical thinking, and a more comprehensive understanding of Ecology concepts⁹⁰.

Based on these findings, the study recommends that Biology teachers should be trained to effectively implement Problem-based Learning in their classrooms. Additionally, workshops, seminars, and conferences should be organized to equip teachers with the necessary skills to integrate Problem-based Learning into their instructional methods. Furthermore, curriculum planners should consider incorporating Problem-based Learning strategy into the Biology curriculum, particularly in the teaching of Ecology, to improve students' learning experiences and academic performance. This study highlights the importance of innovative teaching methods in science education. By adopting Problem-based Learning, educators can foster a more engaging and interactive learning environment that enhances students' understanding, retention, and problem-solving skills in Ecology and beyond⁹⁰.

This study explored the effect of Problem-based Learning (PBL) and Hands-On Activities on the academic performance of secondary school students in Biology. Recognizing the need for more effective teaching methods, the research aimed to

determine whether these approaches could enhance students' understanding and achievement compared to traditional instructional methods. A quasi-experimental design was adopted, specifically a non-equivalent control group design with pre-and post-tests. The study population included 2,691 students from 32 public secondary schools in Nsukka. Using a multi-stage sampling procedure, the researchers selected 85 Senior Secondary Two (SS2) students from two intact classes. To measure students' academic performance, a Biology Achievement Test (BAT) was developed as the primary data collection instrument. The data were analyzed using mean and standard deviation to answer the research questions, while Analysis of Covariance (ANCOVA) was used to test the null hypotheses⁹¹.

The findings of the study revealed a significant difference in students' academic achievement based on the teaching method used. Students who were taught Biology using Hands-On Activities performed significantly better than those taught through traditional methods, demonstrating a deeper understanding and better retention of biological concepts. This suggests that engaging students in practical, interactive learning experiences enhances their comprehension and overall academic performance⁹¹.

Based on these findings, the study recommends that Biology teachers incorporate hands-on activities into their teaching strategies to improve students' engagement and learning outcomes. Additionally, workshops, orientation courses, and seminars should be organized to train teachers on how to effectively implement hands-on activities in Biology instruction. Furthermore, curriculum planners should integrate activity-based learning approaches into the Biology curriculum to maximize student achievement and foster a more interactive learning environment. In conclusion, the study underscores the

effectiveness of hands-on activities in improving students' academic performance in Biology. By actively engaging students in learning processes, these approaches enhance comprehension, retention, and problem-solving skills, making Biology education more practical, engaging, and effective⁹¹.

This study explored the effectiveness of Project-based Learning (PBL) in improving learning activities and scientific literacy including attitude, context, knowledge, and competence among Primary Education Postgraduate students at Bengkulu University in natural science subjects. The research aimed to determine whether the Project-based Learning model could enhance students' engagement and their ability to apply scientific knowledge effectively. A Classroom Action Research approach was employed, conducted over three cycles during the first semester of the 2019/2020 academic year. Data were collected through observations, tests, and rubrics, focusing on students' learning activities, environmental awareness, and health consciousness. The research instruments included a Higher-Order Thinking Skills (HOTS) test, a rubric for assessing student performance, and a student report assessment sheet for evaluating scientific aspects. The study established clear success indicators, requiring that both lecturers and students demonstrate effective engagement with PjBL and that at least 80% of students achieve a good level in scientific literacy components; attitude, context, knowledge, and competence⁹².

The results demonstrated that using the Project-based Learning model significantly enhanced students' learning activities and scientific literacy. Students showed greater participation, improved understanding of scientific concepts, and a stronger ability to apply knowledge in real-life contexts. The study concludes that

Project-based Learning is an effective instructional strategy for improving scientific literacy and learning engagement in natural science subjects. It is recommended that educators integrate Project-based Learning approaches into science instruction to foster critical thinking, problem-solving skills, and real-world application of knowledge. Additionally, lecturers should receive training on implementing Project-based learning effectively to maximize its benefits for students. By adopting Project-based learning, educational institutions can enhance student-centered learning, promote scientific inquiry, and develop competent, knowledgeable, and environmentally conscious graduates in science education⁹².

2.3.3 Gender and Academic Achievement in Ecology

This longitudinal study explores the development and impact of math and science gender stereotypes among high school students, their parents, and teachers. The study sought to answer three main questions: What is the prevalence of gender stereotypes regarding math and science among high school students, their parents, and teachers? Are there any relationships between parents' and teachers' gender stereotypes and the stereotypes held by adolescents? How do adolescents' gender stereotypes influence their math and science identity, and how does this impact their academic outcomes? The research utilized a nationally representative sample of 22,190 U.S. adolescents, including 50% girls, and gathered data from both their parents and teachers. The students were surveyed in 9th and 11th grades, and their transcripts were collected at the end of high school⁹³.

The findings revealed that adolescents' gender stereotypes became significantly more traditional as they progressed from 9th to 11th grade. Additionally, parents were found to be three times more likely to believe that males are better at math and science than females, and there was a significant correlation between parents' and adolescents' gender stereotypes. Furthermore, the study found that adolescent' gender stereotypes in math and science were strongly related to their math and science identity, which, in turn, was associated with their STEM outcomes throughout high school. This study provides valuable insights into how academic gender stereotypes develop during adolescence and how the beliefs held by parents and teachers can influence students' academic identities and performance in STEM subjects. It underscores the need for strategies to challenge these stereotypes in order to promote greater equity in STEM education⁹³.

This study employed a mixed-methods research design to compare the academic performance of males and females studying STEM subjects at both the university and senior high school levels. Additionally, the study explored the factors that contribute to gender differences in academic performance at these two levels of education. The results indicated that at the senior high school level, males outperformed females academically. However, at the tertiary level, females' academic performance showed a notable improvement relative to males. Gender stereotypes were identified as a major contributor to the academic performance gap at the high school level. At the tertiary level, improvements in females' academic performance were attributed to several factors, including teaching methodologies, motivational support from parents, and advocacy campaigns aimed at empowering women⁹⁴.

In contrast, the study found that males' academic performance at the university level was negatively impacted by their participation in extra-curricular activities and other economic ventures. These activities, influenced by broader socio-economic factors, such as financial constraints and gendered ideologies, were seen as contributing to the academic underperformance of males. The study recommends a balanced focus on both females and males in STEM education. While it is crucial to promote the inclusion of more females in STEM disciplines and careers, there is an equally important need to address the challenges facing males. This can be achieved through continuous education and sensitization regarding gender stereotypes, as well as implementing policy measures to support and sustain the academic success of both genders in STEM, contributing to overall national development⁹⁴.

Despite the importance of Biology for sustainable development, students' performance in the subject has been inconsistent. Various interventions have been implemented to improve students' learning of Biology, yet the issue of performance inconsistency persists. In response, this study aimed to investigate the role of hands-on learning in enhancing students' academic achievement in Biology. The study employed a pretest-posttest control group quasi-experimental research design with a 2x2 factorial setup. It also explored the moderating effect of gender on students' academic achievement. The participants consisted of 58 students enrolled in Biology courses at two randomly selected schools. These students were from intact classes, which made the groups naturally assigned. The data was collected using a 25-item Biology Achievement Test for Students (BATS), which was validated for both face and content validity. A test-retest reliability method yielded a reliability coefficient of 0.68⁹⁵.

Data analyses revealed a significant difference in the effect of the learning strategy on students' academic achievement in Biology ($F(1, 53) = 8.595, p = 0.05$), with the conventional method of teaching being more effective. However, the study found no significant difference in the effect of gender on academic achievement ($F(1, 53) = 0.980, p > 0.05$). The researchers concluded that while hands-on activities are essential for enhancing Biology learning, the conventional teaching method proved more effective in improving student achievement. Consequently, the study recommends that school authorities allocate adequate time for hands-on learning activities to improve student outcomes in Biology⁹⁵.

The study assessed the academic performance of SS II male and female Biology students who were taught using the Talent Learning Management System (LMS) and those taught through the expository method. A quasi-experimental design was employed, specifically a non-randomized pre-test post-test control group design. The study was conducted in Uyo Local Government Area of Akwa Ibom State, with a population of 3,183 SS II Biology students across 15 public secondary schools in the area for the 2023/2024 academic session. A purposive sampling technique was used to select schools from the target population, resulting in a sample size of 216 students, comprising 110 females and 106 males. Data was collected using the Biology Performance Test (BPT), which underwent face and content validation by an expert in test measurement and evaluation to ensure the accuracy, appropriateness, and completeness for the study. The instrument had a reliability coefficient of 0.86, indicating high reliability⁹⁶.

Descriptive statistics, including mean, standard deviation, and mean gain scores, were used to answer the research questions, while Analysis of Covariance (ANCOVA)

was used to test all the null hypotheses at a 0.05 significance level. The findings concluded that Talent LMS significantly enhances the academic performance of secondary school students in Biology in Uyo Local Government Area. The study revealed a significant difference in the academic performance between students taught with Talent LMS and those taught using the expository method. Additionally, the study showed that there was no significant difference in the academic performance of male and female students taught using either Talent LMS or the expository method. Based on the results, the study recommends that teachers should incorporate Talent LMS into the teaching of Biology to improve students' academic performance, as it can enhance learning and academic outcomes⁹⁶.

This study aimed to examine the academic achievement of Senior Secondary School students in Biology and to explore the gender differences in students' performance. The ex-post facto design of descriptive research was adopted for this study. Data were collected using a proforma from a sample of 200 students selected using stratified random sampling from Science secondary schools in Kano State, Nigeria. The data collection was specifically focused on the students' performance in Biology achievement tests conducted as part of the qualifying examinations in the region⁹⁷.

The analysis of the data revealed several significant findings. The internal consistency reliability of the Biology achievement test used in the study was found to be low and unsatisfactory. The test's low reliability raised concerns about its effectiveness in accurately measuring students' academic abilities in Biology. Overall, the students' performance in the Biology tests was below average, with the mean score of the sample being 47.02 and a standard deviation of 16.493. This indicated that students were

struggling to perform well in Biology, with a significant number of students failing to meet the expected standard. The mean score of 47% reflected a clear gap between students' actual performance and the desired academic standards in the subject⁹⁷.

Further analysis revealed that gender differences existed in the academic achievement of students in Biology. Specifically, the study found that male students consistently performed better than their female counterparts in the Biology tests. This difference in performance based on gender suggested that gender-related factors might be influencing the academic achievement of students in the subject. The findings highlighted the need for further investigation into the factors that contribute to this gender gap in academic performance. For instance, societal expectations, teaching methods, and access to resources might contribute to the disparity in achievement between male and female students⁹⁷.

Another critical finding of the study was the significant difference in academic performance between students from urban and rural schools. Students from urban schools performed better than their counterparts in rural schools. This disparity could be attributed to several factors, such as better access to educational resources, more qualified teachers, and greater exposure to extracurricular learning opportunities in urban areas. On the other hand, students in rural schools might face challenges such as inadequate learning materials, limited access to qualified teachers, and a lack of facilities, all of which can negatively impact their academic performance in Biology⁹⁷.

The study also concluded that the Biology test used in the Kano State qualifying examinations was not a reliable tool for assessing students' true academic potential in the subject. The low reliability of the test suggests that the assessment method may not

accurately capture students' knowledge and abilities, potentially leading to skewed or incomplete evaluations of their academic progress. The findings underscored the importance of developing more reliable and valid assessment tools that can accurately measure students' understanding of Biology and other subjects⁹⁷.

In addition to the concerns about the assessment tool's reliability, the study also pointed to the unsatisfactory academic performance of students in Biology in general. The overall poor performance reflected the need for significant improvements in teaching methods, curriculum design, and support systems in schools. It was evident that students were not adequately prepared to meet the challenges of the subject, and the low performance rates called for urgent reforms in the way Biology is taught and assessed at the secondary school level⁹⁷.

Moreover, the study highlighted the differential performance between male and female students, as well as between students from urban and rural areas. The results indicated that factors such as gender, school location, and socioeconomic conditions could have a profound impact on students' academic achievement. The gender gap in performance raised important questions about the role of gender stereotypes and cultural expectations in shaping students' academic outcomes, particularly in subjects like Biology, which may be perceived as more male-dominated in some contexts⁹⁷.

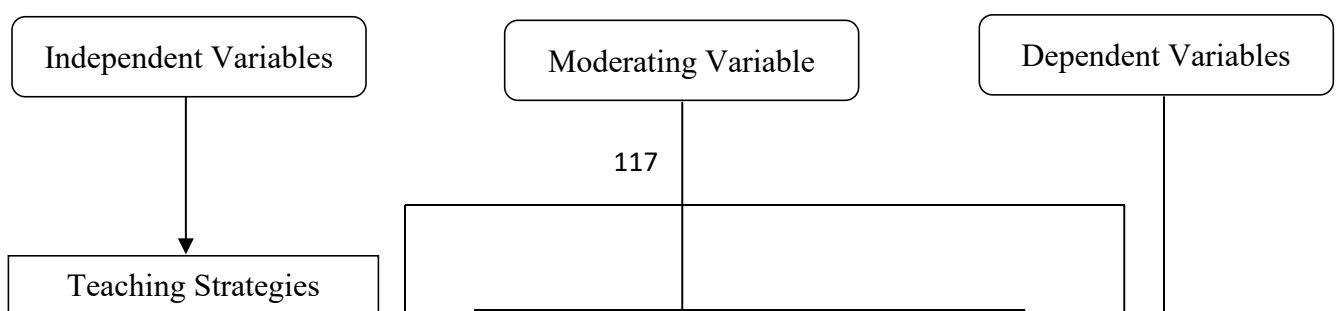
The study's findings have important implications for measurements and evaluation of student learning. It called for a review and reform of the assessment tools used to measure students' academic abilities, emphasizing the need for more reliable and valid instruments. Additionally, the study stressed the importance of addressing the gender disparities in academic performance, ensuring that both male and female students

have equal opportunities to succeed in Biology and other subjects. Teachers, school administrators, and policymakers were urged to focus on creating an inclusive learning environment that supports all students, regardless of their gender or geographical location⁹⁷.

Furthermore, the study suggested that improving the teaching methods and learning resources in rural schools could help bridge the performance gap between urban and rural students. This could involve providing better access to educational materials, training teachers to adopt more effective teaching strategies, and increasing funding for schools in rural areas. In urban schools, it was recommended that efforts be made to sustain and further improve the quality of education, ensuring that all students are given the best possible opportunity to perform well academically⁹⁷.

The study provided valuable insights into the factors influencing students' academic performance in Biology in Kano State, Nigeria. It identified significant differences in performance based on gender, school location, and the reliability of assessment tools. The study concluded that the Biology tests used in Kano State qualifying examinations were not a reliable measure of students' academic abilities, and that more reliable, valid, and inclusive assessment methods should be developed. The findings also underscored the need for ongoing efforts to address gender disparities and geographical inequalities in education, with a focus on improving the quality of Biology education at both the urban and rural school levels⁹⁷.

2.4 Conceptual Model



$$H_{01} (F_{(1, 55)} = 160.770)$$

$$H_{04} (F_{(5, 84)} = 40.191)$$

$$H_{03} (F_{(1, 88)} = 0.002)$$

$$H_{02} (F_{(1, 57)} = 79.050)$$

Figure 2.1: Conceptual Model of Team-based and Project-based Learning Strategies on Academic Achievement in Ecology

Source: Researcher's Fieldwork, 2025

2.5 Summary of Literature Reviewed

The literature reviewed provides a clear foundation for understanding how academic achievement, gender, and teaching strategies influence learning outcomes in Biology, especially in the Ecology component. Academic achievement is shaped by several factors including instructional methods and learner characteristics. Biology, as a subject, demands both theoretical knowledge and practical engagement, particularly in Ecology, which explores the interaction between organisms and their environment. Research supports the use of interactive methods like Team-Based and Project-Based

Learning to enhance understanding in complex topics like Ecology, as these strategies promote collaboration, critical thinking, and hands-on learning.

Team-Based Learning fosters group engagement and accountability, encouraging students to work through problems together, while Project-Based Learning allows them to investigate real-life ecological issues, deepening their understanding and making learning more meaningful. In contrast, traditional methods like lectures are more teacher-centered and may limit student engagement, though they remain relevant in delivering structured content.

Gender differences also play a role in science learning, with studies showing that male and female students may respond differently to teaching strategies, affecting their participation and performance. This underscores the need for inclusive approaches that consider diverse learning preferences.

The study is anchored in Constructivist Learning Theory, which emphasizes learner-centered, experience-based education. This theory supports the effectiveness of active strategies in fostering meaningful learning in Ecology. Empirical findings confirm that both Team-Based and Project-Based Learning improve academic outcomes and student engagement, while gender-sensitive instruction enhances participation across board. The conceptual model derived from this review highlights the interplay between gender, teaching methods, and academic performance in Ecology, providing a framework for testing the study's hypotheses.

Endnotes

1. D. J. Madigan & L. E. Kim, *Does Teacher Burnout affect Students? A Systematic Review of its Association with Academic Achievement and Student-Reported Outcomes*, **International Journal of Educational Research**, 105, 2021, 101714.
2. S. O. Egwu & E. C. Okigbo, *Effect of Field Trip on Secondary School Students' Academic Achievement in Ecology in Anambra State*, **South Eastern Journal of Research and Sustainable Development (SEJRSD)**, 4(1), 2021, 140 – 156.
3. Y. Kotera, E. Taylor, D. Fido, D. Williams & F. Tsuda-McCaie, *Motivation of UK Graduate Students in Education: Self-Compassion Moderates Pathway from Extrinsic Motivation to Intrinsic Motivation*, **Current Psychology**, 42(12), 2023, 10163-10176.

4. S. Nawabi, R. Bilal & M. Q.Javed, *Team-based Learning versus Traditional Lecture-Based Learning: An Investigation of Students' Perceptions and Academic Achievements*, **Pakistan Journal of Medical Sciences**, 37(4),2021, 1080.
5. H. W. Brink, M. G. Loomans, M. P. Mobach & H. S. Kort, *Classrooms' Indoor Environmental Conditions affecting the Academic Achievement of Students and Teachers in Higher Education: A Systematic Literature Review*, **Indoor Air**, 31(2), 2021, 405-425.
6. C. Kassaw&V.Demareva, *Determinants of Academic Achievement among Higher Education Student found in Low Resource Setting, A Systematic Review*, **Plos One**, 18(11), 2023, e0294585.
7. K. S. Uralovich, T. U. Toshmamatovich, K. F. Kubayevich, I. B. Sapaev, S. S. Saylaubaevna, Z. F. Beknazarova & A. Khurramov, *A Primary Factor in Sustainable Development and Environmental Sustainability is Environmental Education*, **Caspian Journal of Environmental Sciences**, 21(4), 2023, 965-975.
8. D. R. Inogamova & L. A. Shigakova, *Efficiency of the Implementation of Modern Virtual Programs for Teaching Biology*, **American Journal of Social Sciences and Humanity Research**, 3(02), 2023, 100-107.
9. K. Barnogul & T.Khilola, *The Essence of the Biological Education Process, Teaching Printouts and Legislation*, **Asian Journal of Multidimensional Research**, 11(4), 2022, 129-133.
10. H. Semilarski & A. Laius, *Exploring Biological Literacy: A Systematic Literature Review of Biological Literacy*, **European Journal of Educational Research**, 10(3), 2021, 1181-1197.
11. G. S. Adewumi, *Effect of Problem-solving Strategy on Students' Academic Performance in Genetic Concepts in Biology in Senior Secondary Schools in Kogistage, Nigeria*, **Journal of Language and Culture in Education**, 1(2), 2024, 106-114.
12. G. Eymur, F. YeşildağHasançebi & P. S. Çetin, *The Influence of Nature of Science embedded in the Argument-Driven Inquiry Instructional Method to Promote Content Knowledge and Self-Efficacy of Pre-Service Science Teachers in Evolution*, **Journal of Biological Education**, 58(3), 2024, 552-569.
13. E. A. Skinner, N. P. Rickert, J. W. Vollet &T. A.Kindermann, *The Complex Social Ecology of Academic Development: A Bioecological Framework and Illustration Examining the Collective Effects of Parents, Teachers, and Peers on Student Engagement*, **Educational Psychologist**, 57(2), 2022, 87-113.

14. S. H. J.Putra, *The Effect of Science, Environment, Technology, and Society (SETS) Learning Model on Students' Motivation and Learning Outcomes in Biology*, **Tarbawi: Jurnal Ilmu Pendidikan**, 17(2), 2021, 145-153.
15. A. A.Oka, *Utilizing Digital Applications in Improving Student Learning Outcomes (Review of Biology Teaching and Learning Strategies)*, **International Research Journal of Management, IT and Social Sciences**, 8(5), 2021, 476-486.
16. S. Bilici & R. M.Yilmaz, *The Effects of Using Collaborative Digital Storytelling on Academic Achievement and Skill Development in Biology Education*, **Education and Information Technologies**, 2, 2024, 1-24.
17. K. T. Hambabi, N. L. L. Tileni & C.Moses, *Exploring Teachers' Perspectives and Challenges in Implementing the Revised Biology Education Curriculum: A Case Study of the Ompundja Circuit*, **Creative Education**, 15(5), 2024, 838-855.
18. D. Wu & Y.Hu, *Construction of New Engineering Talent Training Mode from the Perspective of Innovation Ecology—Optimization and Innovation Path of University and Industry Cooperation Mechanism*, **Journal of Human Resource Development**, 6(2), 2024, 20-27.
19. B. H. Tran, *Sowing Seeds of Climate Awareness: Cultivating a Curriculum for Eco-Consciousness* (Doctoral dissertation, California State University, Northridge), 2024.
20. A. Alam, *Intelligence Unleashed: An Argument for AI-Enabled Learning Ecologies with Real World Examples of Today and A Peek into the Future*. In AIP Conference Proceedings, 2717(1).2023, 1-10.
21. S. C. Anderson, P. R. Elsen, B. B. Hughes, R. K. Tonietto, M. C. Bletz, D. A. Gill & D. Veríssimo, *Trends in Ecology and Conservation over Eight Decades*, **Frontiers in Ecology and the Environment**, 19(5), 2021, 274-282.
22. K. R. Munasi & S. Msezane, *Educational Ecology: Examining the Interplay of Teaching Strategies, Resources, and Guidelines in Integrating EE/ESD into Life Science Curriculum: Integrating EE/ESD into Life Science Curriculum*, **International Journal of Curriculum and Instruction**, 17(1), 2025, 238-264.
23. C. Hall, A. N. Ott, A. Paxton, L. Rivas & G. F.Thomas, *Socializing Ecological Psychology, Ecologizing Social Psychology: How Reuben Baron Shaped the Ecological Approach to Social Knowing, Cooperation, and Values*, **Ecological Psychology**, 36(4), 2024, 271-282.

24. K. J. Kroeker & E. Sanford, *Ecological Leverage Points: Species Interactions Amplify the Physiological Effects of Global Environmental Change in the Ocean*, **Annual Review of Marine Science**, 14(1), 2022, 75-103.
25. I. S. Akbarovna, *The Importance of Pedagogical Management in Education*, **Psixologiya va Sotsiologiya Ilmiy Jurnal**, 2(4), 2024, 40-46.
26. L. L. D. Mallillin, *Instructional Teaching Theory: Basis for Effective Teaching Device in Learning*, **Eureka: Journal of Educational Research**, 2(2), 2024, 120-132.
27. M. B. Ndebil & C. A. Ali, *Cooperative Learning as a Strategy of Improving Mathematics Performance and Attitudes*, **International Journal of Educational Innovation and Research**, 3(1), 2024, 62-74.
28. R. I. Enebechi, *Effect of Inquiry-Based Learning Approach on Senior Secondary School Students' Retention in Biology*, **British International Journal of Education and Social Sciences**, 8(8), 2021, 1 – 12.
29. I. Mohammed, H. Zakari, J. M. Bako, Y. Isa, Y. Abdullahi & A. G. Jibrin, *Impact of Project-based Learning Strategy on Academic Performance of Secondary School Students in Ecology in Bauchi State*, **Journal of Science Technology and Education**, 11(4), 2023, 1 – 8.
30. L. P. Gustafson, *Reflections on Five Years of Team-based Learning in First-Year Property*, **SDL Rev.**, 66, 2021, 29.
31. A. Marks, G. Woolcott & C. Markopoulos, *Differentiating Instruction: Development of a Practice Framework for and with Secondary Mathematics Classroom Teachers*, **International Electronic Journal of Mathematics Education**, 16(3), 2021, em0657.
32. J. Wang & M. Jou, *The Influence of Mobile-Learning Flipped Classrooms on the Emotional Learning and Cognitive Flexibility of Students of Different Levels of Learning Achievement*, **Interactive Learning Environments**, 31(3), 2023, 1309-1321.
33. O. Ajewole & T. Bello, *Effect of Team-based Instructional Strategy On Junior Secondary School Students' Academic Achievement in Basic Science in Ile-Ife, Osun State, Nigeria*. **International Journal of Contemporary Issues in Education**, 4(2), 2022, 11-17.
34. M. Parappilly, R. J. Woodman, & S. Randhawa, *Feasibility and Effectiveness of Different Models of Team-based Learning Approaches in STEM-Based Disciplines*, **Research in Science Education**, 51(1), 2021, 391-405.

35. A. Wullschleger, A. Vörös, B. Rechsteiner, A. Rickenbacher & K. M. Merki, *Improving Teaching, Teamwork, and School Organization: Collaboration Networks in School Teams*, **Teaching and Teacher Education**, 121, 2023, 103909.
36. M. M. Y. Yeung, J. W. M. Yuen, J. M. T. Chen & K. K. L. Lam, *The Efficacy of Team-based Learning in Developing the Generic Capability of Problem-Solving Ability and Critical Thinking Skills in Nursing Education: A Systematic Review*, **Nurse Education Today**, 122, 2023, 105704.
37. C. G. P. Dean, P. Grossman, L. Enumah, Z. Herrmann & S. S. Kavanagh, *Core Practices for Project-based Learning: Learning from Experienced Practitioners in the United States*, **Teaching and Teacher Education**, 133, 2023, 104275.
38. N. G. Ikegbusi & J. U. Egwu, *Impact of Project-based Learning and Student Creativity on Academic Achievement of Public Secondary School Students in Abia State*, **Int'l Journal of Education Research and Scientific Development**, 5(5), 2024, 14-14.
39. S. Koes-H & N. D. Putri, *The Effect of Project-based Learning in STEM on Students' Scientific Reasoning*, In **Journal of Physics: Conference Series**, 1835(1), 2021, 012006.
40. H. B. Issa & A. Khataibeh, *The Effect of Using Project Based Learning on Improving the Critical Thinking among Upper Basic Students from Teachers' Perspectives*, **Pegem Journal of Education and Instruction**, 11(2), 2021, 52-57.
41. S. Z. Ahmed, S. Sultan, M. Kousar, H. A. Basit, R. Zaid & S. Bano, *Effectiveness of Teacher's Centered Approach on Student's Learning at University Level*, **Journal of Positive School Psychology**, 6(10), 2022, 415-428.
42. L. He, N. Yang, L. Xu, F. Ping, W. Li, Q. Sun & H. Zhang, *Synchronous Distance Education vs Traditional Education for Health Science Students: A Systematic Review and Meta-Analysis*, **Medical Education**, 55(3), 2021, 293-308.
43. S. F. Ajmal & M. Hafeez, *Critical Review on Flipped Classroom Model versus Traditional Lecture Method*, **International Journal of Education and Practice**, 9(1), 2021, 128-140.
44. E. Damayanti, A. F. Djollong, A. Asfahani, J. W. Sitopu & U. S. Yadav, *Dynamics of Early Childhood Education in Taiwan: A Comparative Study of Traditional and Innovative Approaches*, **Absorbent Mind: Journal of Psychology and Child Development**, 4(1), 2024, 65-75.

45. A. Santos, R. De Oliveira, & F. Ribeiro, *Islamic Pedagogy and Digital Learning Tools: a Comparative Analysis of Traditional and Online Learning Environments*, **World Journal of Islamic Learning and Teaching**, 1(1), 2024, 23-29.
46. L. Yongsan & Z. Guodong, *The Impact of Physical Education on Student Well-Being: A Comparative Study of Traditional and Innovative Teaching Methods*, **Journal of RoiKaensarnAcademi**, 9(12), 2024, 2656-2663.
47. W. Tu, M. J. B. Z. Abidin, F. Zhang & W. Chen, *Comparison of The Motivation Differences Between Script Teaching Mode and Traditional Teaching Mode for International Business Students in Guangdong Communication Polytechnic*, **Technium Soc. Sci. J.**, 62, 2024, 69.
48. H. Koolivand, M. M. Shooreshi, R. Safari-Faramani, M. Borji, M. S. Mansoori, H. Moradpoor & S. M. Azizi, *Comparison of the Effectiveness of Virtual Reality-Based Education and Conventional Teaching Methods in Dental Education: A Systematic Review*, **BMC Medical Education**, 24(1), 2024, 8.
49. U. K. Durrani, G. Al Naymat, R. M. Ayoubi, M. M. Kamal & H. Hussain, *Gamified Flipped Classroom versus Traditional Classroom Learning: Which Approach is more Efficient in Business Education?*, **The International Journal of Management Education**, 20(1), 2022, 100595.
50. B. D. S. Ghaleb, *Effect of Exam-Focused and Teacher-Centered Education Systems on Students' Cognitive and Psychological Competencies*, **International Journal of Multidisciplinary Approach Research and Science**, 2(2), 2024, 611-631.
51. H. Mizani, A. Cahyadi, H. Hendryadi, S. Salamah, & S. Retno Sari, *Loneliness, Student Engagement, and Academic Achievement during Emergency Remote Teaching During COVID-19: The Role of the God Locus of Control*, **Humanities and Social Sciences Communications**, 9(1), 2022, 1-9.
52. T. Tseer, F. Ngmenkpiao & A. K. Damwah, *Normalised Heteropatriarchy and Performance Disparity among Male and Female Students in Senior High Schools*, **International Journal of Educational Research Open**, 8, 2025, 100425.
53. M. Buenestado-Fernández, G. Ibarra-Vazquez, A. Patiño, & M. S. Ramírez-Montoya, *Stories about Gender Inequalities and Influence Factors: A Science Club Case Study*, **International Journal of Science Education**, 46(5), 2024, 403-420.
54. M. Speechley, J. Stuart & K. L. Modecki, *Diverse Gender Identity Development: A Qualitative Synthesis and Development of a New Contemporary Framework*, **Sex Roles**, 90(1), 2024, 1-18.

55. K. N. Kuteesa, C. U. Akpuokwe & C. A. Udeh, *Gender Equity in Education: Addressing Challenges and Promoting Opportunities for Social Empowerment*, **International Journal of Applied Research in Social Sciences**, 6(4), 2024, 631-641.
56. J. Alghneimin, A. Varga & M. Kovacs, *Gender Disparities and Potentials in Stem Approach in Jordan and Saudi Arabia—An Analytical Literature Review*, **Hungarian Educational Research Journal**, 14(2), 2024, 217-230.
57. H. Hasanuddin, *Profile Students' Thinking Style from Perspective Gender in Learning Activity*, **Jurnal Diversita**, 7(2), 2021, 267-273.
58. S. Korlat, M. Kollmayer, J. Holzer, M. Lüftenegger, E. R. Pelikan, B. Schober & C. Spiel, *Gender Differences in Digital Learning During COVID-19: Competence Beliefs, Intrinsic Value, Learning Engagement, and Perceived Teacher Support*, **Frontiers in Psychology**, 12, 2021, 637776.
59. H. Eslen-Ziya & T. M. Yildirim, *Perceptions of Gendered-Challenges in Academia: How Women Academics see Gender Hierarchies as Barriers to Achievement*, **Gender, Work & Organization**, 29(1), 2022, 301-308.
60. L. Keller, F. Preckel, J. S. Eccles & M. Brunner, *Top-Performing Math Students in 82 Countries: An Integrative Data Analysis of Gender Differences in Achievement, Achievement Profiles, and Achievement Motivation*, **Journal of Educational Psychology**, 114(5), 2022, 966.
61. J. R. Becker & J. Hall, *Research on Gender and Mathematics: Exploring New and Future Directions*, **ZDM—Mathematics Education**, 56(1), 2024, 141-151.
62. J. L. B. Kærsgaard, M. K. Christensen, P. Y. Søndergaard & J. Naukkarinen, *Gender Differences in Dentistry: A Qualitative Study on Students' Intrinsic and Extrinsic Motivations for Entering Dentistry at Higher Education*, **European Journal of Dental Education**, 25(3), 2021, 495-505.
63. T. Jansen, J. Meyer, A. Wigfield & J. Möller, *Which Student and Instructional Variables are most Strongly Related to Academic Motivation in K-12 Education? A Systematic Review of Meta-Analyses*, **Psychological Bulletin**, 148(1-2), 2022, 1.
64. M. Kaya & C. Erdem, *Students' Well-Being and Academic Achievement: A Meta-Analysis Study*, **Child Indicators Research**, 14(5), 2021, 1743-1767.
65. S. Goulas, S. Griselda & R. Megalokonomou, *Comparative Advantage and Gender Gap in STEM*, **Journal of Human Resources**, 59(6), 2024, 1937-1980.

66. I. Y. Marange & B. Tatira, *Gender Dynamics in Geogebra Integration: In-Service Mathematics Teachers' Development*, **EURASIA Journal of Mathematics, Science and Technology Education**, 20(6), 2024, em2457.
67. T. D. Callaghan, N. Richard, C. Campbell & J. Anderson, *Gender Socialization and Supportive School Settings for Elementary-Aged LGBTIQ+ Children*, **Children and Youth Services Review**, 161, 2024, 107611.
68. A. Saleem, H. Kausar & F. Deeba, *Social Constructivism: A New Paradigm in Teaching and Learning Environment*, **Perennial Journal of History**, 2(2), 2021, 403-421.
69. H. Lindqvist & C. Forsberg, *Constructivist Grounded Theory and Educational Research: Constructing Theories About Teachers' Work When Analysing Relationships Between Codes*, **International Journal of Research & Method in Education**, 46(2), 2023, 200-210.
70. L. Wu, P. J. Hsieh & S. M. Wu, *Developing Effective E-Learning Environments Through E-Learning use Mediating Technology Affordance and Constructivist Learning Aspects for Performance Impacts: Moderator of Learner Involvement*, **The Internet and Higher Education**, 55, 2022, 100871.
71. S. Chuang, *The Applications of Constructivist Learning Theory and Social Learning Theory on Adult Continuous Development*, **Performance Improvement**, 60(3), 2021, 6-14.
72. M. R. Arpentieva, H. Retnawati, T. A. Akhmetova, M. N. A. Azman, G. K. Kassymova, *Constructivist Approach in Pedagogical Science*, **Challenges of Science**, IV, 2021, 12-17. Available online: <https://doi.org/10.31643/2021.02>.
73. S. Wibowo, M. N. Wangid & F. M. Firdaus, *The Relevance of Vygotsky's Constructivism Learning Theory with the Differentiated Learning Primary Schools*, **Journal of education and learning (Edu Learn)**, 19(1), 2025, 431-440.
74. S. Ejupi & F. Ajdini, *Basic Cognitive Constructivist Approaches in Language Learning (Object Performance Focus (OPF), Using Podcasting as a Resource)*, **ANGLISTICUM. Journal of the Association-Institute for English Language and American Studies**, 13(1), 2024, 41-48.
75. F. M. Jumaah, *Exploring Constructivist Learning Theory and its Applications in Teaching English*, **The American Journal of Social Science and Education Innovations**, 6(08), 2024, 7-19.

76. S. Fatimah, D. N. Rosidin & A. Hidayat, *Student-Based Learning in the Perspective of Constructivism Theory and Maieutics Method*, **International Journal of Social Science and Human Research**, 5(5), 2022, 1632-1637.
77. Z. R. Kusumawardana & S. Akhiriyah, *EFL University Students' Metacognitive Awareness of Reading Strategy and its Correlation with their Reading Comprehension*, **Linguistics and ELT Journal**, 10(1), 2022, 1-15.
78. R. B. Toma, I. Yáñez-Pérez & J. Á. Meneses-Villagrà, *Towards a Socio-Constructivist Didactic Model for Integrated STEM Education*, **Interchange**, 55(1), 2024, 75-91.
79. A. Nurhuda, M. F. Al Khoiron, Y. S. I. Azami & S. J. Ni'mah, *Constructivism Learning Theory in Education: Characteristics, Steps and Learning Models*, **Research in Education and Rehabilitation**, 6(2), 2023, 234-242.
80. R. Fadli, H. D. Surjono, R. C. Sari, F. Eliza, M. Hakiki, Y. Hidayah & A. D. Samala, *Effectiveness of Mobile Virtual Laboratory Based on Project-based Learning to Build Constructivism Thinking*, **International Journal of Interactive Mobile Technologies**, 18(6), 2024, 40.
81. H. Lindqvist & C. Forsberg, *Constructivist Grounded Theory and Educational Research: Constructing Theories about Teachers' Work when Analysing Relationships Between Codes*, **International Journal of Research & Method in Education**, 46(2), 2023, 200-210.
82. L. M. Arcila Hernández, K. R. Zamudio, A. G. Drake & M. K. Smith, *Implementing Team-Based Learning in the Life Sciences: A Case Study in an Online Introductory Level Evolution and Biodiversity Course*, **Ecology and Evolution**, 11(8), 2021, 3527-3536.
83. N. Kalu-Uche & C. P. Emeka, *Jigsaw Learning Teams, Teacher-Led Discussion and Secondary School Students' Academic Performance in Biology*, **Journal of the Nigerian Academy of Education**, 14(1), 2018, 13-22.
84. R. C. Samosa, *Cooperative Learning Approach as Innovation to Improve Students' Academic Achievement and Attitude in Teaching Biology*, **Journal of World Englishes and Educational Practices**, 3(1), 2021, 01-10.
85. E. P. Driessen, A. E. Wilson, I. Hall, P. Brewer, S. Odom, S. B. Ramsey & C. J. Ballen, *Group Work Enhances Student Performance in Biology: A Meta-Analysis*, **BioScience**, 74(3), 2024, 207-217.

86. T.Talan, *The Effect of Computer-Supported Collaborative Learning on Academic Achievement: A Meta-Analysis Study*, **International Journal of Education in Mathematics, Science, and Technology (IJEMST)**, 9(3), 2021, 426-448. Available online: <https://doi.org/10.46328/ijemst.1243>
87. N. Nuraini, I. H. Asri & N.Fajri, *Development of Project Based Learning with STEAM Approach Model Integrated Science Literacy in Improving Student Learning Outcomes*, **Jurnal Penelitian Pendidikan IPA**, 9(4), 2023, 1632–1640. Available online: <https://doi.org/10.29303/jppipa.v9i4.2987>
88. E. D. M. Nasir & D.Andrew, *Problem Solving in an Online Project Based Learning for Biology Subject*, *International Conference on Business Studies and Education (ICBE)*, 2024, 14-38. Available online: <https://www.icbe.my/wp-content/uploads/2024/06/2.pdf>
89. G.B.T. Usman, N.M. Ali & M.Z.Ahmad, *Effectiveness of STEM Problem-based Learning on the Achievement of Biology among Secondary School Students in Nigeria*, **Journal of Turkish Science Education**, 20(3), 2023, 453- 467.
90. H. Yahaya, *The Effects of Problem-based Learning on Academic Achievement in Ecology Concepts among Science Education Students in Gusau*, **Glob Acad J Humanit Soc Sci**, 5(4), 2023, 194-199.
91. A. L.Nwankwo, T. U. Ugwu, G. Ukala & O. O.Benson, *The Effect of Hands-On Activity and Problem-based Learning on Achievement of Biology Students in Enugu State*, **Inornatus: Biology Education Journal**, 4(1), 2024, 46-56.
92. E. W. Winarni & E. P.Purwandari, *Project-based Learning to Improve Scientific Literacy for Primary Education Postgraduate Students in Science Subject*, **Jurnal Prima Edukasia**, 8(1), 2020, 67-77. Available online: [doi:https://doi.org/10.21831/jpe.v8i1.30618](https://doi.org/10.21831/jpe.v8i1.30618)
93. C. R. Starr & S. D. Simpkins, *High School Students' Math and Science Gender Stereotypes: Relations with their STEM Outcomes and Socializers' Stereotypes*, **Social Psychology of Education**, 24(1), 2021, 273-298.
94. C. Wrigley-Asante, C. G. Ackah & L. K. Frimpong, *Gender Differences in Academic Performance of Students Studying Science Technology Engineering and Mathematics (STEM) Subjects at the University of Ghana*, **S N Social Sciences**, 3(1), 2023, 12.

95. P.A.Onanuga, A.O. Saka & R.P. Ogwo khademhe, *Learning Biology for Sustainable Development Using Hands-On Strategy: Can Gender Achievement Gap Reduce?*, **Unnes Science Education Journal**, 10(1), 2021, 1-11.
96. I. N. Udosen & S. N. Edem, *Assessment of the Academic Performance of SSII Male and Female Biology Students taught using Talent Learning Management Systems (LMS) and those taught with Expository Method*, **Intercontinental Journal of Education, Science and Technology**, 8(1), 2024, 85-97.
97. A. A. Bichi Yusuf, F. Ibrahim, R. H. Ibrahim, *Assessment of Students Performances in Biology: Implication for Measurements and Evaluation of Learning*, **Journal of Education and Learning (EduLearn)**, 13(3), 2019, 301-308. Available online: DOI:10.11591/edulearn.v13i3.12200

Chapter Three Methodology

This chapter covered the research design; population of the study; sample and sampling techniques; description of research instruments; validation of research instruments; reliability of research instrument; data collection; and data analysis method for the study.

3.1 Research Design

This study employed the quasi-experimental research design with 3×2 Factorial matrix using pre-test and post-test approach. The three levels of treatment are focused on two experimental groups and one control group. Group A and Group B received team-based and project-based learning strategies, respectively, while Group C, the control group, received traditional strategy. Tables 3.1 and 3.2 provide more details about the research schema.

Table 3.1: Research Schema

Group	1 (Pretest)	Treatment	2 (Posttest)
G ₁	O ₁	X ₁	O ₂
G ₂	O ₃	X ₂	O ₄
G ₃	O ₅	X ₃	O ₆

Source: Researcher's Fieldwork, 2025

Where O₁, O₃, O₅ = Pretest Scores

O₂, O₄, O₆ = Posttest Scores

G₁, G₂, G₃ = Treatment Groups

X₁ = Treatment 1 (Team-based learning strategy)

X₂ = Treatment 2 (Project-based learning strategy)

X₃ = Control (Traditional teaching strategy)

Table 3.2: Schematic Representation of the 3×2 Factorial Matrix

Treatment		Gender	Academic Achievement
Team-based learning strategy	X ₁	Male / Female	
Project-based learning strategy	X ₂	Male / Female	

Traditional teaching strategy	X ₃	Male / Female
-------------------------------	----------------	---------------

Source: Researcher's Fieldwork, 2025

Variables in the study

1. Independent variable includes:
 - Treatment 1 (Team-based learning strategy)
 - Treatment 2 (Project-based learning strategy)
 - Control (Traditional teaching strategy)
2. Moderating variable includes: Gender
 - Male
 - Female
3. Dependent variable includes: Achievement at One Level
 - Achievement in Ecology

3.2 Population of the Study

As at the time of conducting this research, the study population comprises 3,680 students, of which 1,706 are male and 1,974 are female. The students are from all public SS II classes from 40 public senior secondary schools found in the three Local Government Areas of the Abeokuta Metropolis, specifically Abeokuta North, Abeokuta South and Odeda Local Government Areas, Ogun State. Additional details about the study population were provided in Table 3.3.

Table 3.3: Study Population

Abeokuta Metropolis LGAs	Number of Schools	SS II Enrollments		
		Male	Female	Total
Abeokuta North LGA.	14	657	754	1,411

Abeokuta South LGA.	14	549	705	1,254
Odeda LGA	12	500	515	1,015
Total	40	1,706	1,974	3,680

Source¹

3.3 Sample and Sampling Techniques

For this study, a total of 40 public Senior Secondary Schools across Abeokuta North, Abeokuta South, and Odeda Local Government Areas (LGAs) of Ogun State was considered. However, only three schools were selected based on specific criteria to ensure uniformity in educational standards and fair representation of student demographics. The selection process focused on government-owned schools that offer Biology up to the Senior Secondary School Certificate (SSSC) level and meet essential academic and infrastructural requirements.

To systematically identify the most suitable schools, the researcher conducted field visits to public senior secondary schools in each of the three LGAs to gather essential information. The selection criteria includes:

1. The number of Biology teachers handling Senior Secondary II (SS II) classes.
2. The availability of a Biology laboratory to support practical learning.
3. The presence of a well-equipped and functional laboratory for effective instruction.
4. The qualification of Biology teachers, ensuring they hold at least a B.Sc., B.Sc. (Ed.), or PGDE.
5. The selected schools must be a co-educational institution to enhance and improve the generalizability of the study's findings.

The selection process using multistage sampling procedure was carried out in three stages:

Stage One: Schools that do not meet the stated criteria were excluded from the study.

Stage Two: The remaining schools that fulfill all the requirements were grouped according to their respective LGAs. From each group, one school was randomly selected to participate in the study.

Stage Three: If a selected school has multiple intact SS II Biology classes, one was randomly chosen to ensure fairness. The Biology teachers handling the selected classes participated in the study as research assistants.

To ensure an unbiased allocation, the balloting method was employed. The names of the three LGAs were written on separate pieces of paper, folded, shuffled, and drawn at random. The first LGA picked was designated as Group A (Experimental Group 1), the second as Group B (Experimental Group 2), and the third as Group C (Control Group).

Following the draw:

1. Abeokuta North was assigned to Group A (Experimental Group 1).
2. Abeokuta South was assigned to Group B (Experimental Group 2).
3. Odeda was assigned to Group C (Control Group).

Similarly, a balloting method was used to assign the selected schools to specific experimental and control groups. Based on the draw:

1. Abeokuta Grammar School, situated in Abeokuta North LGA, was assigned to Experimental Group A, where students received the Team-based Learning (TBL) strategy as the treatment.

2. Rev. Kuti Memorial Grammar School, Abeokuta, situated in Abeokuta South LGA, was assigned to Experimental Group B, where students received the Project-based Learning (PBL) strategy as the treatment.
3. Nawair-ur-Deen Grammar School, Obantoko, situated in Odeda LGA, was assigned to Control Group C, where students were taught using the Traditional Teaching Strategy.

Additional details on the random sampling used to select three public secondary schools for the study were provided in Table 3.4.

Table 3.4: Random Sampling for selected Public Senior Secondary Schools

Random Selected Schools	Treatment Groups	Respective LGAs
Abeokuta Grammar School	Group A	Abeokuta North LGA.
Rv. Kuti Memorial Grammar School, Abeokuta	Group B	Abeokuta South LGA.
Nawair-ur-Deen Grammar School, Obantoko	Group C	Odeda LGA.

Source¹

This structured selection process ensured that the study is conducted in a fair and unbiased manner, maintaining validity and reliability. By using multistage sampling procedure and random allocation, the study effectively assessed the impact of team-based and project-based learning strategies compared to the traditional teaching strategy in the teaching of Ecology.

For this study, a sample size of intact classes were taken from each of the random selected public Senior Secondary Schools.

3.4 Description of the Research Instruments

The following instruments were used to collect data for this study:

1. Ecology Achievement Test (EAT)
2. Instructional Guide for Teaching and Learning Ecology based on Team-based Learning Strategy
3. Instructional Guide for Teaching and Learning Ecology based on Project-based Learning Strategy
4. Instructional Guide for Teaching and Learning Ecology based on Traditional Teaching Strategy

3.4.1 Ecology Achievement Test (EAT)

This instrument was used to gather information for the study to evaluate the academic achievement of Ecology. Twenty distinct items drawn from previous Biology Senior Secondary Certificate Examination (SSCE) questions based on Ecology only made up the instrument. The items were multiple-choice, meaning that participants were only able to choose one correct response at a time from options labeled with the letters A – D. Forty-five minutes were allotted for answering all the questions.

There were two sections (A and B) in the Ecology Achievement Test (EAT). Section A included the participants' demographic data, such as their school name and gender. Section B consisted of 20 multiple-choice questions addressing the concept of Ecology. The item specifications for the 20 multiple-choice questions, arranged according to the higher order of cognitive levels (Bloom's Taxonomy: Knowledge, Comprehension, Application and Analysis), are shown in Table 3.5.

Table 3.5: Table of Specification

Cognitive Level	Number of Items	Total	Percentage %
------------------------	------------------------	--------------	---------------------

Knowledge	1, 2, 3, 5, 9, 11, 13, 14, 16, 20	10	50
Comprehension	4, 6, 8, 10, 12, 15, 18	7	35
Application	7, 17	2	10
Analysis	19	1	5
Total	20	20	100

Source: Researcher's Fieldwork, 2025

Further information regarding Ecology Achievement Test (EAT) and its respective answer as marking guide can be found in Appendix I and II, respectively.

3.4.2 Instructional Guide for Teaching and Learning Ecology based on Team-based Learning Strategy

Lesson notes for teaching ecology using the team-based learning strategy including specific teacher and student activities spans two class periods (90 minutes each) and outlines both teacher and student activities for teaching ecology through team-based learning. By combining individual preparation with collaborative problem-solving, students can deepen their understanding of ecological principles and develop essential skills for teamwork and critical thinking. This guide for instruction in teaching and learning process in selected schools for the study during fieldwork which consists of lesson overview (topic, grade level, duration, learning objectives, presentation and assessment). Further information regarding instructional guide for experimental Group A (Lesson Notes I) can be found in Appendix III.

3.4.3 Instructional Guide for Teaching and Learning Ecology based on Project-based Learning Strategy

Lesson notes for teaching Ecology using project-based learning strategy spans two class periods (90 minutes each) and emphasizes independent research and personal engagement. This detailed lesson notes leverages project-based learning to engage students in exploring the impact of human activities on ecosystems. By emphasizing personal inquiry and independent research, students can develop a deeper understanding of ecological concepts while honing their presentation and communication skills. This guide for instruction in teaching and learning process in selected schools for the study during fieldwork consists of lesson overview (topic, grade level, duration, learning objectives, presentation and assessment). Further information regarding instructional guide for experimental Group B (Lesson Notes II) can be found in Appendix IV.

3.4.4 Instructional Guide for Teaching and Learning Ecology based on Traditional Teaching Strategy

Lesson notes for teaching Ecology using a traditional teaching strategy spans two class periods (90 minutes each) and covers the key concepts of Ecology, focusing on direct instruction, lectures and individual assessments. This lesson notes employ a traditional teaching strategy to deliver foundational knowledge in Ecology. By focusing on direct instruction, lectures, and individual assessments, students gain a structured understanding of ecological concepts. While traditional strategy had their limitations, they provide a clear framework for students to build knowledge and prepare for further exploration in Ecology and Environmental science. This guide for instruction in teaching

and learning process in selected schools for the study during fieldwork consists of lesson overview (topic, grade level, duration, learning objectives, presentation and assessment). Further information regarding instructional guide for Control Group C (Lesson Notes III) can be found in Appendix V.

3.5 Validity of the Research Instruments

Prior to utilizing the research instruments, to assess participants' academic achievement in Ecology, the thesis promoter and two other lecturers (experts) in the Department of Science Education, Lead City University, Ibadan validated the instrument based on face, content and construct validity. All corrections and suggestions were effected before the final drafts were produced for administration.

3.6 Reliability of the Research Instrument

A different group of participants within the population who did not partake in the main study but share similar characteristics with the randomly selected public secondary schools students for the study were given the Ecology Achievement Test to calculate the instrument's reliability value using Kuder-Richardson (KR-20) formula that result to 0.76.

3.7 Methods of Data Collection

Research assistants (Biology teachers) received training on study-specific teaching strategies during the first week of fieldwork. During the training session, the objectives of the study and the procedures needed to complete it in eight (8) weeks were thoroughly explained. Participants were given the pretest during the second week. For the following five weeks (weeks three through seven), each of the randomly selected public

secondary schools for the study had its treatment plan implemented according to the designated teaching strategy. The posttest was administered in the eighth week. In the purposive selected public senior secondary schools for the study, Biology teachers (research assistants) were trained with the use of the team-based learning strategy instructional guide for experimental group A, the project-based learning strategy instructional guide for experimental group B, and the traditional teaching strategy with researcher-prepared lesson notes for control group C. After the training, the researcher tested the research assistants' or Biology teachers' understanding of the subject matter by observing them carries out the experiment for 30 minutes under close supervision. Participants in the experimental and control groups experienced the same amount of time (periods). In each school, a period was employed to deliver the treatment once a week for five (5) weeks (week three through week seven). The participants had a pre-test before the experiment starts and a post-test at the conclusion of the experiment.

3.8 Methods of Data Analysis

Inferential statistics was used to analyze the data collected using Analysis of Covariance (ANCOVA) at the 0.05 level of significance to test the hypotheses formulated for the study.

3.9 Ethical Approval

Ethical research procedures were followed in this project to guarantee the anonymity, respect, and voluntary involvement of all participants. In order to introduce the researcher to the authorities of the purposive selected public secondary schools for the study, the researcher received a Letter of Introduction from the Head of Department. Through this letter, official consent was requested to interact with participants and carry out the study, which included giving the achievement test to gather data. All participants were asked for their informed consent prior to the study starting. There was a comprehensive consent form available that explains the goal, methods, possible advantages, and potential drawbacks of the study. The freedom to leave the study at any time without facing any consequences is one of the rights that participants were guaranteed. The researcher guaranteed that information gathered were treated with the utmost confidentiality and used only for scholarly research. To preserve their privacy, participant identities and answers were anonymised. No participant was forced to participate in the study; participation was completely voluntary. The study was conducted in accordance with the strictest guidelines for research integrity and participant autonomy.

Endnote

1. Teaching Service Commission, *Public Senior Secondary Schools (SS II) Population in Abeokuta Metropolis*, Ogun State TESCOM, 2024.

Chapter Four

Results and Discussion of Findings

This chapter presents result tables, the interpretation of results and discussion of findings.

4.1 Demographic Data Analysis

Table 4.1.0: Team-based Learning Strategy, Project-based Learning Strategy and Traditional Teaching Strategy

Teaching Strategies	Gender	Total
----------------------------	---------------	--------------

	Male	Female	
Team-based Learning Strategy	14	17	31
Project-based Learning Strategy	15	18	33
Traditional Teaching Strategy	15	12	27
Total	44	47	91

Source: Researcher's Fieldwork, 2025

4.2 Presentation of Data

4.2.1 Hypotheses

H₀₁: There will be no significant main effect of team-based learning strategy on Senior Secondary School Students' achievement in Ecology in the Abeokuta Metropolis, Nigeria.

Table 4.1.1: Tests of Between-Subjects Effects of Team-based Learning Strategy on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria

Dependent Variable: Posttest

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	177.959 ^a	2	88.979	98.475	0.000	0.782
Intercept	241.569	1	241.569	267.349	0.000	0.829
Pretest	42.328	1	42.328	46.845	0.000	0.460
Strategy	145.267	1	145.267	160.770*	0.000	0.745
Error	49.696	55	0.904			
Total	12220.000	58				

Corrected Total	227.655	57
-----------------	---------	----

a. R Squared = 0.782 (Adjusted R Squared = 0.774)

* denote significant at $p \leq 0.05$

Source: Researcher's Fieldwork, 2025

From Table 4.1.1: The Analysis of Covariance (ANCOVA) result on the effect of team-based learning strategy on Senior Secondary School Students' achievement in Ecology in the Abeokuta Metropolis, Nigeria was; $F_{(1; 55)} = 160.770$, $p < 0.05$, partial $\eta^2 = 0.745$. The results clearly show that the team-based learning strategy had a significant and positive impact on students' academic achievement in Ecology. Therefore, the null hypothesis (H_{01}), which states that there will be no significant main effect of team-based learning strategy, is rejected. Thus, there was significant main effect of Team-based learning strategy on Senior Secondary School Students' achievement.

Table 4.1.2: Estimated Marginal Means of Team-based Learning and Traditional Teaching Strategies on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria

Dependent Variable: Posttest				
Strategy	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Team-based Learning	15.860 ^a	0.171	15.517	16.202
Traditional Teaching	12.680 ^a	0.183	12.313	13.047

a. Covariates appearing in the model are evaluated at the following values:

Pretest = 10.29.

Source: Researcher's Fieldwork, 2025

The Estimates Table 4.1.2 presents the adjusted mean posttest scores for each instructional strategy, taking into account the effect of the pretest scores (which are held constant at a value of 10.29). Students who were taught using the team-based learning strategy had an adjusted mean posttest score of 15.860, with a standard error of 0.171. The 95% confidence interval for this estimate ranges from 15.517 to 16.202, indicating high precision and statistical reliability. On the other hand, students who received traditional teaching had an adjusted mean posttest score of 12.680, with a standard error of 0.183, and a 95% confidence interval ranging from 12.313 to 13.047. The difference in adjusted mean scores 15.860 for team-based learning versus 12.680 for traditional teaching demonstrates that students in the team-based learning group performed significantly better than those in the traditional group, even after accounting for their pretest scores. This further supports the earlier findings and provides a clear and practical interpretation: team-based learning leads to higher academic achievement in Ecology among senior secondary school students compared to traditional teaching strategy. Therefore, the null hypothesis (H_01) is rejected.

H₀₂: There will be no significant main effect of project-based learning strategy on Senior Secondary School Students' achievement in Ecology in the Abeokuta Metropolis, Nigeria.

Table 4.2.1: Tests of Between-Subjects Effects of Project-based Learning Strategy on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria

Dependent Variable: Posttest

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	238.735 ^a	2	119.368	132.29	0.000	0.823
Intercept	86.839	1	86.839	96.210	0.000	0.628
Pretest	33.919	1	33.919	37.579	0.000	0.397
Strategy	71.350	1	71.350	79.050*	0.000	0.581
Error	51.448	57	0.903			
Total	13403.000	60				
Corrected Total	290.183	59				

a. R Squared = 0.823 (Adjusted R Squared = 0.816)

* denote significant at $p \leq 0.05$

Source: Researcher's Fieldwork, 2025

From Table 4.2.1: The Analysis of Covariance (ANCOVA) result on the effect of project-based learning strategy on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria was; $F_{(1; 57)} = 79.050$, $p < 0.05$, partial $\eta^2 = 0.581$. The findings clearly demonstrate that the project-based learning strategy significantly improved students' academic performance in Ecology. Therefore, the null hypothesis (H_{02}) is rejected. This means that project-based learning is not only effective but plays a key role in enhancing the academic success of Senior Secondary School Students in this subject. Thus, there was a significant main effect of project-based learning strategy on Senior Secondary School Students' achievement in Ecology.

Table 4.2.2: Estimated Marginal Means of Project-based Learning and Traditional Teaching Strategies on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria

Dependent Variable: Posttest

Strategy	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Project-based Learning	15.983 ^a	0.182	15.618	16.349
Traditional Teaching	13.317 ^a	0.206	12.905	13.728

a. Covariates appearing in the model are evaluated at the following values:
Pretest = 11.63.

Source: Researcher's Fieldwork, 2025

The Estimates Table 4.2.2 presents the adjusted mean posttest scores for students taught using different instructional strategies, with the pretest scores held constant at 11.63. Students who received the project-based learning strategy had an adjusted mean posttest score of 15.983, with a standard error of 0.182. The 95% confidence interval for this estimate ranges from 15.618 to 16.349, showing a high level of precision. In contrast, students who were taught using the traditional teaching strategy had a lower adjusted mean posttest score of 13.317, with a standard error of 0.206 and a 95% confidence interval ranging from 12.905 to 13.728. The difference between the two strategies; a gap of 2.666 points, indicates that students exposed to project-based learning performed significantly better academically than those taught traditionally, even when their pretest scores were the same. These findings confirm that the project-based learning strategy is more effective than the traditional strategy in improving students' academic achievement in Ecology. This further supports the rejection of the null hypothesis (H_02), highlighting the value of innovative, student-centered learning strategy in secondary science education.

H₀₃: There will be no significant main effect of gender on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria.

Table 4.3.1: Tests of Between-Subjects Effects of Gender on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria

Dependent Variable: Posttest

Source	Type Sum Squares	III of	Df	Mean Square	F	Sig.	Partial Squared	Eta
Corrected Model	117.322 ^a		2	58.661	21.411	0.000	0.327	
Intercept	321.810		1	321.810	117.461	0.000	0.572	
Pretest	114.644		1	114.644	41.845	0.000	0.322	
Gender	0.006		1	0.006	0.002	0.963	0.000	
Error	241.095		88	2.740				
Total	21195.000		91					
Corrected Total	358.418		90					

a. R Squared = 0.327 (Adjusted R Squared = 0.312)

Source: Researcher's Fieldwork, 2025

From Table 4.3.1: The Analysis of Covariance (ANCOVA) result on the effect of gender on Senior Secondary School Students' achievement in Ecology; $F_{(1; 88)} = 0.002$, $p > 0.05$, partial $\eta^2 = 0.000$. There is no significant difference in the academic achievement of male and female students in Ecology based on this data. Therefore, the null hypothesis (H_{03}) is retained, affirming that gender does not significantly influence students' academic performance in this subject. Thus, there was no significant main effect of gender on Senior Secondary School Students' Achievement in Ecology.

Table 4.3.2: Estimated Marginal Means of Gender on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria

Dependent Variable: Posttest				
Gender	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Female	15.140 ^a	0.243	14.657	15.622
Male	15.123 ^a	0.251	14.625	15.622

a. Covariates appearing in the model are evaluated at the following values: Pretest = 11.13.

Source: Researcher's Fieldwork, 2025

The Estimates Table 4.3.2 shows the adjusted mean posttest scores for male and female students in Ecology, with pretest scores held constant at 11.13. Female students had an adjusted mean score of 15.140, with a standard error of 0.243. The 95% confidence interval for this estimate ranges from 14.657 to 15.622. Male students had an almost identical adjusted mean score of 15.123, with a standard error of 0.251 and a 95% confidence interval ranging from 14.625 to 15.622. The very close means and overlapping confidence intervals indicate that there is no meaningful difference in academic achievement between male and female students in Ecology when controlling for their prior knowledge. This further confirms that gender does not significantly influence students' performance, supporting the conclusion that the null hypothesis (H_0) should be retained.

H₀₄: There will be no significant interaction effect of Team-based learning strategy, Project-based learning strategy and gender on senior secondary school students' achievement in Ecology in the Abeokuta Metropolis, Nigeria.

Table 4.4.1: Tests of Between-Subjects Effects of Team-based Learning Strategy, Project-based Learning Strategy and Gender on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria

Dependent Variable: Posttest

Source	Type Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	287.345 ^a	6	47.891	56.602	0.000	0.802
Intercept	288.913	1	288.913	341.462	0.000	0.803
Pretest	60.277	1	60.277	71.241	0.000	0.459
Strategy x Gender	170.028	5	34.006	40.191*	0.000	0.705
Error	71.073	84	0.846			
Total	21195.000	91				
Corrected Total	358.418	90				

a. R Squared = 0.802 (Adjusted R Squared = 0.788)

* denote significant at $p \leq 0.05$

Source: Researcher's Fieldwork, 2025

From Table 4.4.1: The Analysis of Covariance (ANCOVA) result on the effects of team-based learning strategy, project-based learning strategy and gender on Senior Secondary School Students' achievement in Ecology; $F_{(5, 84)} = 40.191$, $p < 0.05$, partial $\eta^2 = 0.705$. This implies that students' performance is not only affected by the teaching strategies used but also by how these strategies interact with gender. Therefore, the null hypothesis (H_{07}) is rejected. Thus, there was significant interaction effect of team-based learning strategy, project-based learning strategy and gender on Senior Secondary School Students' achievement in Ecology.

Table 4.4.2: Estimated Marginal Means of Team-based Learning Strategy, Project-based Learning Strategy and Gender on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria

Dependent Variable: Posttest

Gender	Strategy	Mean	Std. Error	95% Interval	Confidence
				Lower Bound	Upper Bound
Female	Project-based Learning	15.672 ^a	0.233	15.209	16.135
	Team-based Learning	16.145 ^a	0.224	15.699	16.592
	Traditional Teaching	13.016 ^a	0.267	12.484	13.548
Male	Project-based Learning	16.027 ^a	0.245	15.540	16.514
	Team-based Learning	16.300 ^a	0.258	15.787	16.813
	Traditional Teaching	13.042 ^a	0.240	12.564	13.519

a. Covariates appearing in the model are evaluated at the following values: Pretest = 11.13.

Source: Researcher's Fieldwork, 2025

From Table 4.4.2: The estimated marginal means of posttest scores provide insight into how different instructional strategies; project-based learning, team-based learning, and traditional teaching, affected male and female students' academic achievement in Ecology. For female students, those taught through team-based learning achieved the highest mean posttest score of 16.145, followed by those taught through project-based learning with a mean of 15.672. Female students exposed to traditional teaching recorded a significantly lower average score of 13.016. Similarly, male students also performed best with team-based learning, scoring a mean of 16.300, slightly higher than their female counterparts. Those taught through project-based learning had a mean score of 16.027, while those in the traditional group scored the lowest at 13.042. The consistency in pattern across genders highlights a clear trend: both team-based and project-based learning strategies significantly improved academic outcomes in Ecology compared to the traditional teaching strategy, with team-based learning being the most

effective overall. Although male students had slightly higher scores in each strategy, the differences between genders were minimal, indicating that the observed gains are largely attributable to the instructional strategies rather than gender alone.

4.3 Discussion of Findings

There was a significant main effect of team-based learning strategy on senior secondary school students' achievement in Ecology. This indicates that students taught with team-based learning performed markedly better than those taught with traditional strategy. This outcome aligns with the findings from the study "Implementing Team-Based Learning in the Life Sciences" where team-based learning promoted student engagement, collaboration, and deeper understanding of scientific concepts¹. The structured nature of team-based learning characterized by pre-class preparation, readiness assurance testing, and application-focused group tasks clearly contributed to improved performance. This supports the call for adopting team-based learning in science education to foster accountability and active participation, especially in large classes or virtual settings.

The current findings also align with the findings of a study carried out in Abia State, where students in the jigsaw learning team, a similarly collaborative strategy, also performed better than those taught traditionally, although the latter study's difference was not statistically significant². This suggests that when properly implemented, structured group learning significantly enhances academic outcomes in Ecology. Similarly, this study outcome aligns with the results of the cooperative learning study: "Cooperative Learning Approach as Innovation to Improve Students' Academic Achievement and

Attitude in Teaching Biology," which reported a higher percentage improvement in the experimental group's academic achievement compared to the control group, though the difference was not statistically significant³. The team-based approach employed in this study, with its emphasis on collaboration, accountability, and peer interaction, seems to yield a more pronounced impact on student learning than the general cooperative strategies previously examined.

The study result supports the meta-analytic conclusion that group-based learning strategies significantly enhance student achievement from the meta-analysis titled "Group Work Enhances Student Performance in Biology: A Meta-Analysis⁴." Both studies underscore the value of structured collaboration in promoting deeper understanding and improved outcomes in science education, particularly when such strategies are sustained and assessed. This study result also aligns with the meta-analysis findings, titled "The Effect of Computer-Supported Collaborative Learning on Academic Achievement: A Meta-Analysis Study," which reported a moderate effect size for Computer-Supported Collaborative Learning (CSCL), confirming that structured peer collaboration; whether digitally facilitated or in-person positively influences student achievement⁵. Both studies suggest that cooperative engagement enhances understanding, particularly when learning involves complex concepts such as Ecology.

There was significant main effect of project-based learning strategy on Senior Secondary School Students' achievement in Ecology indicates that students who engaged in project-based tasks performed considerably better in Ecology than those taught through traditional strategy. This finding aligns with the outcomes of the STEAM-integrated model study titled: "Development of Project-Based Learning with STEAM

Approach Model Integrated Science Literacy in Improving Student Learning Outcomes," where project-based learning effectively enhanced students' grasp of ecosystem concepts, demonstrated by an N-Gain score⁶. In both cases, project-based learning allowed students to explore scientific concepts more deeply through hands-on tasks, problem-solving, and real-world applications; key elements for developing science literacy and improving academic achievement.

Students taught using this strategy performed notably better than their peers who received instruction through the traditional strategy. This finding resonates with the outcomes of the Field Trip Teaching Strategy (FTIS) employed in this study titled: "Effect of Field Trip on Secondary School Students' Academic Achievement in Ecology in Anambra State", where students engaged in experiential learning also showed superior performance compared to those taught via conventional lectures⁷. The success of both project-based learning and field trips highlights a common thread; active, student-centered instruction that immerses learners in real-world tasks. This strategy not only promote deeper understanding but also help bridge the gap between classroom theory and practical application.

This finding confirms that students who participated in project-based activities performed significantly better than their counterparts who were taught using the conventional strategy. This outcome aligns closely with the study on "Effectiveness of STEM Problem-Based Learning on the Achievement of Biology among Secondary School Students in Kebbi State," which emphasized inquiry and student-driven exploration. By allowing students to engage in hands-on tasks, construct knowledge, and investigate real-world biological problems such as diffusion and osmosis, project-based

learning facilitates deeper understanding and long-term retention⁸. The improvement in achievement supports the notion that activity-based instructional strategy, like Project-Based Learning and STEM- Project-Based Learning, enable learners to process and internalize concepts more effectively than passive listening.

There was no significant main effect of gender on Senior Secondary School Students' achievement in Ecology. The analysis showed no statistically significant main effect of gender on students' academic achievement in Ecology. This indicates that male and female students performed comparably, regardless of the instructional strategy used. This outcome contrasts with widespread gender stereotypes reported in the longitudinal study titled: "High School Students' Mathematics and Science Gender Stereotypes: Relations with their STEM Outcomes and Socializers' Stereotypes," where parents and students increasingly perceived male as more capable in science subjects⁹. The finding is encouraging, as it suggests that when students are given equal access to learning resources and innovative teaching strategies, such as Ecology-focused active learning, gender does not inherently determine academic performance. It also implies that equitable instructional strategies can help neutralize the impact of stereotypical gender beliefs.

The results revealed no statistically significant main effect of gender on academic achievement. This means male and female students performed similarly in Ecology, regardless of the instructional strategy applied. This finding contrasts with the Ghanaian study titled: "Gender Differences in Academic Performance of Students Studying Science, Technology, Engineering and Mathematics (STEM) Subjects at the University of Ghana," where male were found to outperform female in STEM subjects at the Senior

High School level¹⁰. The absence of a gender gap in the study suggests that the use of engaging and equitable teaching strategies may help neutralize the influence of gender stereotypes, especially when students are equally supported in the classroom. It supports the assertion that teaching methodologies play a pivotal role in reducing performance disparities and empowering all learners.

The results indicated no statistically significant main effect of gender on students' academic achievement. This finding aligns with the conclusion drawn in the referenced hands-on Biology study titled: "Learning Biology for Sustainable Development Using Hands-On Strategy: Can Gender Achievement Gap Reduce?" which similarly found no significant difference in academic performance between male and female students¹¹. Both studies suggest that when students are equally exposed to structured instructional strategies whether conventional or activity-based; gender alone does not determine achievement levels. This challenges persistent assumptions about inherent gender-based academic capabilities in science subjects, indicating that other factors such as teaching quality and classroom engagement may have greater influence.

The result of this hypothesis revealed no statistically significant effect of gender on academic achievement, suggesting that both male and female students performed similarly in Ecology. This finding resonates with the conclusion from the Talent Learning Management Systems (LMS) study titled: "Assessment of the Academic Performance of SSII Male and Female Biology Students Taught Using Talent Learning Management Systems (LMS) and those taught with Expository Method," which showed no significant difference in the academic performance of male and female students taught with either Talent Learning Management Systems (LMS) or the expository method. These findings

challenge the stereotype that one gender performs inherently better in science subjects than the other. They also affirm that when exposed to effective teaching strategies, both male and female students have equal potential to succeed¹².

The result indicated no statistically significant effect of gender on academic achievement, suggesting that male and female students performed similarly in Ecology. This outcome contrasts with findings from the Kano State study titled: “Assessment of Students’ Performances in Biology: Implication for Measurements and Evaluation of Learning,” which reported that male students consistently outperformed female in Biology achievement tests¹³. The difference in these findings reflect the influence of instructional context and the quality of learning strategies adopted. While the Kano study relied on performance in standardized tests whose reliability was later questioned; the study implemented practical and engaging instructional strategies that may have equalized learning opportunities for both genders. This suggests that when students are taught with inclusive and active learning strategies, the gender gap in academic achievement can be significantly reduced.

There was significant interaction effect of team-based learning strategy, Project-based learning strategy and gender on Senior Secondary School Students’ achievement in Ecology with the highest academic performance recorded among students, both male and female who were taught using team-based learning. This confirms the strong influence of team-based learning on learning outcomes, consistent with its documented success in life sciences education. The findings support the notion that team-based learning fosters deeper cognitive processing and knowledge retention regardless of gender from the study “Implementing Team-Based Learning in the Life Sciences: A Case Study in an Online

Introductory Level Evolution and Biodiversity Course”. In the online evolution and biodiversity course cited, students expressed a stronger sense of belonging and ownership of their learning through team-based learning, a reflection echoed in the study where strategy had more impact than gender¹.

The interaction of strategy and gender confirmed that students, regardless of gender, performed best when taught using the team-based learning strategy, followed by project-based learning, with traditional teaching yielding the least performance. This underscores the adaptability and inclusiveness of these strategies. While the jigsaw learning study in Abia State emphasized the need for varied and interactive strategies to support comprehension, the study provides robust statistical backing to confirm the effectiveness of such approaches, especially when instructional design considers gender inclusivity and engagement².

A significant interaction was observed between instructional strategy and gender, confirming that team-based learning had the most substantial effect on achievement, regardless of gender. While the Cooperative Learning study: "Cooperative Learning Approach as Innovation to Improve Students' Academic Achievement and Attitude in Teaching Biology," showed slight but similar improvements in student attitudes in both the experimental and control groups, it did not establish statistical significance³. In contrast, this study's results clearly support the robust impact of well-structured, interactive teaching strategies on academic achievement across genders.

Students, regardless of gender, achieved best when exposed to both strategies. This finding echoes the effectiveness of the integrated STEAM project-based model, which promoted inclusive learning and resulted in marked performance gains for all

students⁶. The evidence suggests that combining varied, student-centered strategies provides a balanced, engaging, and equitable classroom environment that enhances overall academic success.

Lead City University Ibadan DO NOT COPY

Endnotes

1. L. M. Arcila Hernández, K. R. Zamudio, A. G. Drake & M. K. Smith, *Implementing Team-Based Learning in the Life Sciences: A Case Study in an Online Introductory Level Evolution and Biodiversity Course*, **Ecology and Evolution**, 11(8), 2021, 3527-3536.
2. N. Kalu-Uche & C. P. Emeka, *Jigsaw Learning Teams, Teacher-Led Discussion and Secondary School Students' Academic Performance in Biology*, **Journal of the Nigerian Academy of Education**, 14(1), 2018, 13-22.
3. R. C. Samosa, *Cooperative Learning Approach as Innovation to Improve Students' Academic Achievement and Attitude in Teaching Biology*, **Journal of World Englishes and Educational Practices**, 3(1), 2021, 01-10.
4. E. P. Driessen, A. E. Wilson, I. Hall, P. Brewer, S. Odom, S. B. Ramsey & C. J. Ballen, *Group Work Enhances Student Performance in Biology: A Meta-Analysis*, **Bio Science**, 74(3), 2024, 207-217.
5. T. Talan, *The Effect of Computer-Supported Collaborative Learning on Academic Achievement: A Meta-Analysis Study*, **International Journal of Education in Mathematics, Science, and Technology (IJEMST)**, 9(3), 2021, 426-448. Available online: <https://doi.org/10.46328/ijemst.1243>
6. N. Nuraini, I. H. Asri & N. Fajri, *Development of Project Based Learning with STEAM Approach Model Integrated Science Literacy in Improving Student Learning Outcomes*, **Jurnal Penelitian Pendidikan IPA**, 9(4), 2023, 1632–1640. Available online: <https://doi.org/10.29303/jppipa.v9i4.2987>
7. S. O. Egwu & E. C. Okigbo, *Effect of Field Trip on Secondary School Students' Academic Achievement in Ecology in Anambra State*, **South Eastern Journal of Research and Sustainable Development (SEJRSD)**, 4(1), 2021, 140 – 156.
8. G.B.T. Usman, N.M. Ali & M. Z. Ahmad, *Effectiveness of STEM Problem-based Learning on the Achievement of Biology among Secondary School Students in Nigeria*, **Journal of Turkish Science Education**, 20(3), 2023, 453- 467.
9. C. R. Starr & S. D. Simpkins, *High School Students' Math and Science Gender Stereotypes: Relations with their STEM Outcomes and Socializers' Stereotypes*, **Social Psychology of Education**, 24(1), 2021, 273-298.
10. C. Wrigley-Asante, C. G. Ackah & L. K. Frimpong, *Gender Differences in Academic Performance of Students Studying Science Technology Engineering and Mathematics (STEM) Subjects at the University of Ghana*, **S N Social Sciences**, 3(1), 2023, 12.

11. P.A.Onanuga, A.O. Saka & R. P. Ogwokhademhe, *Learning Biology for Sustainable Development Using Hands-On Strategy: Can Gender Achievement Gap Reduce?*, **Unnes Science Education Journal**, 10(1), 2021, 1-11.
12. I. N. Udosen & S. N. Edem, *Assessment of the Academic Performance of SSII Male and Female Biology Students taught using Talent Learning Management Systems (LMS) and those taught with Expository Method*, **Intercontinental Journal of Education, Science and Technology**, 8(1), 2024, 85-97.
13. A. A. Bichi Yusuf, F. Ibrahim & R. H. Ibrahim, *Assessment of Students Performances in Biology: Implication for Measurements and Evaluation of Learning*, **Journal of Education and Learning (EduLearn)**, 13(3), 2019, 301-308. Available online: DOI:10.11591/edulearn.v13i3.12200

Chapter Five Conclusion

5.1 Summary of Findings

This study determined the effects of team and project-based learning strategies on Senior Secondary School Students' Achievement in Ecology in the Abeokuta Metropolis, Nigeria with total of 91 participants (44 male and 47 female students) from the three randomly selected schools for the study; Abeokuta Grammar School, situated in Abeokuta North LGA, assigned to Experimental Group A, where students received the Team-based Learning (TBL) strategy as the treatment comprising 31 participants (14 male and 17 female students). Rev. Kuti Memorial Grammar School, Abeokuta, situated in Abeokuta South LGA, assigned to Experimental Group B, where students received the Project-based Learning (PBL) strategy as the treatment comprising 33 participants (15 male and 18 female students). Nawair-ur-Deen Grammar School, Obantoko, situated in Odeda LGA, assigned to Control Group C, where students taught using the Traditional Teaching Strategy comprising 27 participants (15 male and 12 female students).

From the Analysis of Covariance (ANCOVA) results: There was significant main effect of team-based learning strategy on Senior Secondary School Students' achievement in Ecology ($F_{(1; 55)} = 160.770$, $p < 0.05$, partial $\eta^2 = 0.745$).

There was significant main effect of project-based learning strategy on Senior Secondary School Students' achievement in Ecology ($F_{(1; 57)} = 79.050$, $p < 0.05$, partial $\eta^2 = 0.581$).

There was no significant main effect of gender on Senior Secondary School Students' achievement in Ecology ($F_{(1; 88)} = 0.002$, $p > 0.05$, partial $\eta^2 = 0.000$).

There was significant interaction effect of team-based learning strategy, project-based learning strategy and gender on Senior Secondary School Students' achievement in Ecology ($F_{(5; 84)} = 40.191, p < 0.05, \text{partial } \eta^2 = 0.705$).

5.2 Conclusion

The study conclude that team-based and project-based learning strategies significantly enhanced students' academic achievement in Ecology. Although gender alone showed no effect, both male and female students benefited equally from these innovative strategies. The combination of team- and project-based strategies proved most effective, highlighting the need for innovative and student-centered teaching strategies in Secondary School Ecology classrooms.

5.3 Recommendations

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

1. Schools should adopt and integrate team-based learning strategy into the teaching of Ecology to enhance students' academic achievement.
2. Education stakeholders should provide resources and time allocation that support project-based activities.
3. Instructional approaches should focus on individual learning needs rather than gender-based differences.
4. The education system should institutionalize team-based and project-based strategies as core instructional methods, regardless of gender differences.

5.4 Contribution to Knowledge

The study contributes to understanding the effectiveness of team-based and project-based learning strategies in enhancing senior secondary school biology students' academic achievement in ecology. It provides insights into innovative pedagogical approaches that can improve students' understanding and retention of ecological concepts. The research adds to the existing body of knowledge on student-centered learning approaches and their impact on academic achievement in science education.

5.4.1 Implication for Researchers

The study's findings can inform future research on the design and implementation of team-based and project-based learning strategies in science education. Researchers can build upon this study to explore the long-term effects of these strategies on students' academic achievement and motivation. The research methodology and instruments used can serve as a reference for future studies on similar topics.

5.4.2 Implication for Practitioners

Teachers and educators can adopt team-based and project-based learning strategies to enhance students' understanding and achievement in ecology and other science subjects. The study's findings can inform the development of teacher training programs and professional development workshops on innovative pedagogical approaches. Practitioners can use the research's recommendations to design and implement more effective and engaging lesson plans, promoting student-centered learning and improving academic achievement.

5.5 Suggested Area for Further Research

Based on the findings of this study, further research is recommended to explore the long-term effects of team-based and project-based learning strategies on students' retention and application of Biology concepts beyond classroom assessments. Comparative studies could also be conducted across different subjects and educational levels to determine the broader applicability of these strategies. Additionally, future research should examine the influence of cultural, socio-economic, and psychological factors on performance, particularly in science subjects. It would also be valuable to investigate the effectiveness of these instructional approaches in rural and under-resourced schools, where access to quality teaching methods is often limited. Finally, studies focusing on the development and validation of more reliable strategies are essential to ensure accurate measurement of students' academic abilities across diverse learning environments.

Bibliography

Book

- Burgess A. & Matar E., Team-based learning (TBL): Theory, Planning, Practice, and Implementation. In *Clinical Education for the Health Professions: Theory and Practice*, Singapore: Springer Nature Singapore, 2023, 1325-1353.
- Sweet M. & Michaelsen L. K., *Team-based Learning in the Social Sciences and Humanities: Group Work that Works to Generate Critical Thinking and Engagement*, Taylor & Francis, 2023.

Conference

- Alam A., *Intelligence Unleashed: An Argument for AI-Enabled Learning Ecologies with Real World Examples of Today and a Peek into the Future*. In AIP Conference Proceedings, 2717(1).2023, 1-10.
- Nasir E. D. M. & Andrew D., *Problem Solving in an Online Project Based Learning for Biology Subject*, International Conference on Business Studies and Education (ICBE), 2024, 14-38. Available online: <https://www.icbe.my/wp-content/uploads/2024/06/2.pdf>

Dissertation

- Carlos S., Neucir S., Frederico F., Lucas P., Victor P., Ana T., Bruno C., Renata C., Rita V. M. & Benjamin W., *Effectiveness of Active Learning for Ecology Teaching: The Perspective of Students vs their Grades*, 2020, 1 – 34, Available online: DOI:10.1101/2020.04.02.021584.
- Teaching Service Commission, *Public Senior Secondary Schools (SS II) Population in Abeokuta Metropolis*, Ogun State TESCO, 2024.
- Tran B. H., *Sowing Seeds of Climate Awareness: Cultivating a Curriculum for Eco-Consciousness* (Doctoral dissertation, California State University, Northridge), 2024.

Journal

- Abrha M., Kelkay A. D. & Seifu A., *Gender Responsive Pedagogy Practices: Secondary School Science Teachers in Ethiopia*, **Journal of International Women's Studies**, 25(1), 2023, 20.

- Adeosun O. T. & Owolabi K. E., *Gender Inequality: Determinants and Outcomes in Nigeria*, **Journal of Business and Socio-economic Development**, 1(2), 2021, 165-181.
- Adewumi G. S., *Effect of Problem-solving Strategy on Students' Academic Performance in Genetic Concepts in Biology in Senior Secondary Schools in Kogistage, Nigeria*, **Journal of Language and Culture in Education**, 1(2), 2024, 106-114.
- Ahmed S. Z., Sultan S., Kousar M., Basit H. A., Zaid R. & Bano S., *Effectiveness of Teacher's Centered Approach on Student's Learning at University Level*, **Journal of Positive School Psychology**, 6(10), 2022, 415-428.
- Ajewole O. & Bello T., *Effect of Team-based Instructional Strategy On Junior Secondary School Students' Academic Achievement in Basic Science in Ile-Ife, Osun State, Nigeria*, **International Journal of Contemporary Issues in Education**, 4(2), 2022, 11-17.
- Ajmal S. F. & Hafeez M., *Critical Review on Flipped Classroom Model versus Traditional Lecture Method*, **International Journal of Education and Practice**, 9(1), 2021, 128-140.
- Akbarovna I. S., *The Importance of Pedagogical Management in Education*, **Psixologiya va Sotsiologiya Ilmiy Jurnali**, 2(4), 2024, 40-46.
- Akounjom B. J., Babatunde O. & Aigubaruueghian O. M., *The Future of Vocational Education Trends and Innovations in Blended Teaching Methodologies in Nigeria*, **International Journal of Sub-Saharan African Research**, 2(3), 2024, 267-277.
- Alghneimin J., Varga A. & Kovacs M., *Gender Disparities and Potentials in Stem Approach in Jordan and Saudi Arabia—An Analytical Literature Review*, **Hungarian Educational Research Journal**, 14(2), 2024, 217-230.
- Anderson S. C., Elsen P. R., Hughes B. B., Tonietto R. K., Bletz M. C., Gill D. A. & Veríssimo D., *Trends in Ecology and Conservation over Eight Decades*, **Frontiers in Ecology and the Environment**, 19(5), 2021, 274-282.
- Arcila Hernández L. M., Zamudio K. R., Drake A. G. & Smith M. K., *Implementing Team-Based Learning in the Life Sciences: A Case Study in an Online Introductory Level Evolution and Biodiversity Course*, **Ecology and Evolution**, 11(8), 2021, 3527-3536.
- Arpentieva M. R., Retnawati H., Akhmetova T. A., Azman M. N. A., Kassymova G.K., *Constructivist Approach in Pedagogical Science*, **Challenges of Science**, IV, 2021, 12-17. Available online: <https://doi.org/10.31643/2021.02>.

- Barnogul K. & Khilola T., *The Essence of the Biological Education Process, Teaching Printouts and Legislation*, **Asian Journal of Multidimensional Research**, 11(4), 2022, 129-133.
- Becker J. R. & Hall J., *Research on Gender and Mathematics: Exploring New and Future Directions*, **ZDM–Mathematics Education**, 56(1), 2024, 141-151.
- Bichi Yusuf A. A., Ibrahim F., Ibrahim R. H., *Assessment of Students Performances in Biology: Implication for Measurements and Evaluation of Learning*, **Journal of Education and Learning (EduLearn)**, 13(3), 2019, 301-308. Available online: DOI:10.11591/edulearn.v13i3.12200
- Bilici S. & Yilmaz R. M., *The Effects of Using Collaborative Digital Storytelling on Academic Achievement and Skill Development in Biology Education*, **Education and Information Technologies**, 2, 2024, 1-24.
- Brink H. W., Loomans M. G., Mobach M. P. & Kort H. S., *Classrooms' Indoor Environmental Conditions affecting the Academic Achievement of Students and Teachers in Higher Education: A Systematic Literature Review*, **Indoor Air**, 31(2), 2021, 405-425.
- Buenestado-Fernández M., Ibarra-Vazquez G., Patiño A. & Ramírez-Montoya M. S., *Stories about Gender Inequalities and Influence Factors: A Science Club Case Study*, **International Journal of Science Education**, 46(5), 2024, 403-420.
- Callaghan T. D., Richard N., Campbell C. & Anderson J., *Gender Socialization and Supportive School Settings for Elementary-Aged LGBTIQ+ Children*, **Children and Youth Services Review**, 161, 2024, 107611.
- Chuang S., *The Applications of Constructivist Learning Theory and Social Learning Theory on Adult Continuous Development*, **Performance Improvement**, 60(3), 2021, 6-14.
- Damayanti E., Djollong A. F., Asfahani A., Sitopu J. W. & Yadav U. S., *Dynamics of Early Childhood Education in Taiwan: A Comparative Study of Traditional and Innovative Approaches*, **Absorbent Mind: Journal of Psychology and Child Development**, 4(1), 2024, 65-75.
- Dean C. G. P., Grossman P., Enumah L., Herrmann Z. & Kavanagh S. S., *Core Practices for Project-based Learning: Learning from Experienced Practitioners in the United States*, **Teaching and Teacher Education**, 133, 2023, 104275.
- Derkach T. M., Bilianska M. & Yaroshenko O. G., *Project-based Learning as an Approach to Enhance Ecological Component in Professional Education*, **Educational Technology Quarterly**, 2023(4), 2023, 481-497

- Driessen E. P., Wilson A. E., Hall I., Brewer P., Odom S., Ramsey S. B. & Ballen C. J., *Group Work Enhances Student Performance in Biology: A Meta-Analysis*, **Bio Science**, 74(3), 2024, 207-217.
- Durrani U. K., Al Naymat G., Ayoubi R. M., Kamal M. M. & Hussain H., *Gamified Flipped Classroom versus Traditional Classroom Learning: Which Approach is more Efficient in Business Education?*, **The International Journal of Management Education**, 20(1), 2022, 100595.
- Egwu S. O. & Okigbo E. C., *Effect of Field Trip on Secondary School Students' Academic Achievement in Ecology in Anambra State*, **South Eastern Journal of Research and Sustainable Development (SEJRSD)**, 4(1), 2021, 140 – 156.
- Eheazu C. L., *Promoting Conservation Agriculture in Rural Nigeria: Relevance of Environmental Literacy Education*, **International Journal of Agricultural Extension and Rural Development Studies**, 10(1), 2023, 16-37.
- Ejupi S. & Ajdini F., *Basic Cognitive Constructivist Approaches in Language Learning (Object Performance Focus (OPF), Using Podcasting as a Resource)*, **ANGLISTICUM. Journal of the Association-Institute for English Language and American Studies**, 13(1), 2024, 41-48.
- Enebechi R. I., *Effect of Inquiry-Based Learning Approach on Senior Secondary School Students' Retention in Biology*, **British International Journal of Education and Social Sciences**, 8(8), 2021, 1 – 12.
- Eslen-Ziya H. & Yildirim T. M., *Perceptions of Gendered-Challenges in Academia: How Women Academics see Gender Hierarchies as Barriers to Achievement*, **Gender, Work & Organization**, 29(1), 2022, 301-308.
- Eymur G., YeşildağHasançebi F. & Çetin P. S., *The Influence of Nature of Science embedded in the Argument-Driven Inquiry Instructional Method to Promote Content Knowledge and Self-Efficacy of Pre-Service Science Teachers in Evolution*, **Journal of Biological Education**, 58(3), 2024, 552-569.
- Ezeaku F. N., Onu E. A., Agu P. U., Edikpa E. C., Nwafor B. N., Ozioko A. N. & Ugwuanyi C. S., *Appraisal of Quality Assurance Measures in the Management of Secondary Schools and its Implication on Science, Technology, Engineering and Mathematics Education*, **International Journal of Mechanical and Production Engineering Research and Development**, 10(1), 2021, 159-170.
- Fadli R., Surjono H. D., Sari R. C., Eliza F., Hakiki M., Hidayah Y. & Samala A. D., *Effectiveness of Mobile Virtual Laboratory Based on Project-based Learning to Build Constructivism Thinking*, **International Journal of Interactive Mobile Technologies**, 18(6), 2024, 40.

- Farley A. N. & Leonardi B., *Beyond Bathroom Bills and the Gender Identity Debate: Complicating the Policy Conversation about Supporting Trans Students in Schools*, **Educational Policy**, 35(2), 2021, 274-303.
- Fatimah S., Rosidin D. N. & Hidayat A., *Student-Based Learning in the Perspective of Constructivism Theory and Maieutics Method*, **International Journal of Social Science and Human Research**, 5(5), 2022, 1632-1637.
- Ghaleb B. D. S., *Effect of Exam-Focused and Teacher-Centered Education Systems on Students' Cognitive and Psychological Competencies*, **International Journal of Multidisciplinary Approach Research and Science**, 2(2), 2024, 611-631.
- Goulas S., Griselda S. & Megalokonomou R., *Comparative Advantage and Gender Gap in STEM*, **Journal of Human Resources**, 59(6), 2024, 1937-1980.
- Gustafson L. P., *Reflections on Five Years of Team-based Learning in First-Year Property*, **SDL Rev.**, 66, 2021, 29.
- Haatainen O. & Aksela M., *Project-based Learning in Integrated Science Education: Active Teachers' Perceptions and Practices*, **LUMAT: International Journal on Math, Science and Technology Education**, 9(1), 2021, 149-173.
- Hall C., Ott A. N., Paxton A., Rivas L. & Thomas G. F., *Socializing Ecological Psychology, Ecologizing Social Psychology: How Reuben Baron Shaped the Ecological Approach to Social Knowing, Cooperation, and Values*, **Ecological Psychology**, 36(4), 2024, 271-282.
- Hambabi K. T., Tileni N. L. L. & Moses C., *Exploring Teachers' Perspectives and Challenges in Implementing the Revised Biology Education Curriculum: A Case Study of the Ompundja Circuit*, **Creative Education**, 15(5), 2024, 838-855.
- Hasanuddin H., *Profile Students' Thinking Style from Perspective Gender in Learning Activity*, **JurnalDiversita**, 7(2), 2021, 267-273.
- He L., Yang N., Xu L., Ping F., Li W., Sun Q. & Zhang H., *Synchronous Distance Education vs Traditional Education for Health Science Students: A Systematic Review and Meta-Analysis*, **Medical Education**, 55(3), 2021, 293-308.
- Ikegbusi N. G. & Egwu J. U., *Impact of Project-based Learning and Student Creativity on Academic Achievement of Public Secondary School Students in Abia State*, **Int'l Journal of Education Research and Scientific Development**, 5(5), 2024, 14-14.
- Inogamova D. R. & Shigakova L. A., *Efficiency of the Implementation of Modern Virtual Programs for Teaching Biology*, **American Journal of Social Sciences and Humanity Research**, 3(02), 2023, 100-107.

- Isa S. G., Mammam M. A., Badar Y. & Bala T., *The Impact of Teaching Methods on Academic Performance of Secondary School Students in Nigeria*, **International Journal of Development Research**, 10(06), 2020, 37382-37385.
- Issa H. B. & Khataibeh A., *The Effect of Using Project Based Learning on Improving the Critical Thinking among Upper Basic Students from Teachers' Perspectives*, **Pegem Journal of Education and Instruction**, 11(2), 2021, 52-57.
- Jansen T., Meyer J., Wigfield A. & Möller J., *Which Student and Instructional Variables are most Strongly Related to Academic Motivation in K-12 Education? A Systematic Review of Meta-Analyses*, **Psychological Bulletin**, 148(1-2), 2022, 1.
- Jumaah F. M., *Exploring Constructivist Learning Theory and its Applications in Teaching English*, **The American Journal of Social Science and Education Innovations**, 6(08), 2024, 7-19.
- Kabir U., Marty A. H., Akinrinmade B. & Zuilkowski S. S., *An Analysis of Teaching and Learning Materials for Literacy Instruction in Kano State, Nigeria: Curricular Relevance, Cultural Responsiveness and Gender Equity*, **Literacy**, 56(2), 2022, 130-149.
- Kærsgaard J. L. B., Christensen M. K., Søndergaard P. Y. & Naukkarinen J., *Gender Differences in Dentistry: A Qualitative Study on Students' Intrinsic and Extrinsic Motivations for Entering Dentistry at Higher Education*, **European Journal of Dental Education**, 25(3), 2021, 495-505.
- Kalu-Uche N. & Emeka C. P., *Jigsaw Learning Teams, Teacher-Led Discussion and Secondary School Students' Academic Performance in Biology*, **Journal of the Nigerian Academy of Education**, 14(1), 2018, 13-22.
- Kassaw C. & Demareva V., *Determinants of Academic Achievement among Higher Education Student found in Low Resource Setting, A Systematic Review*, **Plos One**, 18(11), 2023, e0294585.
- Kaya M. & Erdem C., *Students' Well-Being and Academic Achievement: A Meta-Analysis Study*, **Child Indicators Research**, 14(5), 2021, 1743-1767.
- Keller L., Preckel F., Eccles J. S. & Brunner M., *Top-Performing Math Students in 82 Countries: An Integrative Data Analysis of Gender Differences in Achievement, Achievement Profiles, and Achievement Motivation*, **Journal of Educational Psychology**, 114(5), 2022, 966.
- Kilag O. K., Tariman R., Dela Cruz R. A., Cantere Jr. G., Niere L. & Priolo V., *Innovative Teaching Strategies in Secondary Science Education: A Systematic Review*, **International Multidisciplinary Journal of Research for Innovation, Sustainability, and Excellence (IMJRISE)**, 1(4), 2024, 37-44. Available online: <https://risejournals.org/index.php/imjrise/article/view/247>

- Koes-H S. & Putri N. D., *The Effect of Project-based Learning in STEM on Students' Scientific Reasoning*, In **Journal of Physics: Conference Series**, 1835(1), 2021, 012006.
- Koolivand H., Shooreshi M. M., Safari-Faramani R., Borji M., Mansoori M. S., Moradpoor H. & Azizi S. M., *Comparison of the Effectiveness of Virtual Reality-Based Education and Conventional Teaching Methods in Dental Education: A Systematic Review*, **BMC Medical Education**, 24(1),2024, 8.
- Korlat S., Kollmayer M., Holzer J., Lüftenegger M., Pelikan E. R., Schöber B. & Spiel C., *Gender Differences in Digital Learning During COVID-19: Competence Beliefs, Intrinsic Value, Learning Engagement, and Perceived Teacher Support*, **Frontiers in Psychology**, 12, 2021, 637776.
- Kotera Y., Taylor E., Fido D., Williams D. & Tsuda-McCaie F., *Motivation of UK Graduate Students in Education: Self-Compassion Moderates Pathway from Extrinsic Motivation to Intrinsic Motivation*, **Current Psychology**, 42(12), 2023, 10163-10176.
- Kroecker K. J. & Sanford E., *Ecological Leverage Points: Species Interactions Amplify the Physiological Effects of Global Environmental Change in the Ocean*, **Annual Review of Marine Science**, 14(1), 2022, 75-103.
- Kusumawardana Z. R. & Akhiriyah S., *EFL University Students' Metacognitive Awareness of Reading Strategy and its Correlation with their Reading Comprehension*, **Linguistics and ELT Journal**, 10(1), 2022, 1-15.
- Kuteesa K. N., Akpuokwe C. U. & Udeh C. A., *Gender Equity in Education: Addressing Challenges and Promoting Opportunities for Social Empowerment*, **International Journal of Applied Research in Social Sciences**, 6(4), 2024, 631-641.
- Lindqvist H. & Forsberg C., *Constructivist Grounded Theory and Educational Research: Constructing Theories about Teachers' Work when Analysing Relationships Between Codes*, **International Journal of Research & Method in Education**, 46(2),2023, 200-210.
- Madigan D. J. & Kim L. E., *Does Teacher Burnout affect Students? A Systematic Review of its Association with Academic Achievement and Student-Reported Outcomes*, **International Journal of Educational Research**, 105, 2021, 101714.
- Mallillin L. L. D., *Instructional Teaching Theory: Basis for Effective Teaching Device in Learning*, **Eureka: Journal of Educational Research**, 2(2), 2024, 120-132.
- Marange I. Y. & Tatira B., *Gender Dynamics in Geogebra Integration: In-Service Mathematics Teachers' Development*, **EURASIA Journal of Mathematics, Science and Technology Education**, 20(6), 2024, em2457.

- Marks A., Woolcott G. & Markopoulos C., *Differentiating Instruction: Development of a Practice Framework for and with Secondary Mathematics Classroom Teachers*, **International Electronic Journal of Mathematics Education**, 16(3), 2021, em0657.
- Mizani H., Cahyadi A., Hendryadi H., Salamah S. & Retno Sari S., *Loneliness, Student Engagement, and Academic Achievement during Emergency Remote Teaching During COVID-19: The Role of the God Locus of Control*, **Humanities and Social Sciences Communications**, 9(1), 2022, 1-9.
- Mohammed I., Zakari H., Bako J. M., Isa Y., Abdullahi Y. & Jibrin A. G., *Impact of Project-based Learning Strategy on Academic Performance of Secondary School Students in Ecology in Bauchi State*, **Journal of Science Technology and Education**, 11(4), 2023, 1 – 8.
- Mukandayisenga S., Opanga D., Nsengimana V., *Teachers' Perceptions on the Effectiveness of the Inquiry-Based Learning towards Students' Achievement in Biology: The Case of schools of Rwanda*, **African Journal of Educational Studies in Mathematics and Sciences**, 17(2), 2021, 1-10. Available online: DOI: <https://dx.doi.org/10.4314/ajesms.v17i2.895>
- Munasi K. R. & Msezane S., *Educational Ecology: Examining the Interplay of Teaching Strategies, Resources, and Guidelines in Integrating EE/ESD into Life Science Curriculum: Integrating EE/ESD into Life Science Curriculum*, **International Journal of Curriculum and Instruction**, 17(1), 2025, 238-264.
- Nawabi S., Bilal R. & Javed M. Q., *Team-based Learning versus Traditional Lecture-Based Learning: An Investigation of Students' Perceptions and Academic Achievements*, **Pakistan Journal of Medical Sciences**, 37(4), 2021, 1080.
- Ndebil M. B. & Ali C. A., *Cooperative Learning as a Strategy of Improving Mathematics Performance and Attitudes*, **International Journal of Educational Innovation and Research**, 3(1), 2024, 62-74.
- Nuraini N., Asri I. H. & Fajri N., *Development of Project Based Learning with STEAM Approach Model Integrated Science Literacy in Improving Student Learning Outcomes*, **Jurnal Penelitian Pendidikan IPA**, 9(4), 2023, 1632–1640. Available online: <https://doi.org/10.29303/jppipa.v9i4.2987>
- Nurhuda A., Al Khoiron M. F., Azami Y. S. I. & Ni'mah S. J., *Constructivism Learning Theory in Education: Characteristics, Steps and Learning Models*, **Research in Education and Rehabilitation**, 6(2), 2023, 234-242.
- Nwankwo A. L., Ugwu T. U., Ukala G. & Benson O. O., *The Effect of Hands-On Activity and Problem-based Learning on Achievement of Biology Students in Enugu State*, **Inornatus: Biology Education Journal**, 4(1), 2024, 46-56.

- Oguguo O. U. & Uboh U. V., *State Based Analysis of Candidates' WASSCE Participation and Achievement of Five Credits Passes and above including Mathematics and English Language in Nigeria*, **International Journal of Advanced Academic Research (Sciences, technology and Engineering)**, 6(6), 2020, 42 – 53. Available online: DOI: 10.46654/ij.24 889849.e6619
- Ogunode N. J., *Basic Education in Nigeria: Challenges and Way Forward*, **Journal of Intellectual Property and Human Rights**, 1(2),2022, 1-13.
- Oka A. A., *Utilizing Digital Applications in Improving Student Learning Outcomes (Review of Biology Teaching and Learning Strategies)*, **International Research Journal of Management, IT and Social Sciences**, 8(5), 2021, 476-486.
- Oladejo A. I., Nwaboku N. C., Okebukola P. A. & Ademola I. A., *Gender Difference in Students' Performance in Chemistry–Can Computer Simulation Bridge the Gap?*, **Research in Science & Technological Education**, 41(3), 2023, 1031-1050.
- Onanuga P. A., Saka A.O. & Ogwohademhe R. P., *Learning Biology for Sustainable Development Using Hands-On Strategy: Can Gender Achievement Gap Reduce?*, **Unnes Science Education Journal**, 10(1), 2021, 1-11.
- Osiesi M. P., Adeniran S. A., Adekoya A. F., Akomolafe O. D., Aruleba A. L. & Blignaut S., *Gender Disparities and Teachers' Soft Skills as Determinants of Learners' Attitude Towards Learning Mathematics in Ekiti State Primary Schools, Nigeria*, **Gender and Behaviour**, 20(4), 2022, 20788-20802.
- Parappilly M., Woodman R. J. & Randhawa S., *Feasibility and Effectiveness of Different Models of Team-based Learning Approaches in STEM-Based Disciplines*, **Research in Science Education**, 51(1), 2021, 391-405.
- Putra S. H. J., *The Effect of Science, Environment, Technology, and Society (SETS) Learning Model on Students' Motivation and Learning Outcomes in Biology*, **Tarbawi: Jurnal Ilmu Pendidikan**, 17(2), 2021, 145-153.
- Putria M., *Gender Equality Analysis in the Learning Process (Case Study on Accounting Department at Vocational High School)*, **International Journal of Health, Education & Social (IJHES)**, 7(11),2024, 61-86.
- Ramdani D. & Susilo H., *The Effectiveness of Collaborative Learning on Critical Thinking, Creative Thinking, and Metacognitive Skill Ability: Meta-Analysis on Biological Learning*, **European Journal of Educational Research**, 11(3), 2022, 1607-1628.
- Saleem A., Kausar H. & Deebea F., *Social Constructivism: A New Paradigm in Teaching and Learning Environment*, **Perennial Journal of History**, 2(2), 2021, 403-421.

- Samosa R. C., *Cooperative Learning Approach as Innovation to Improve Students' Academic Achievement and Attitude in Teaching Biology*, **Journal of World Englishes and Educational Practices**, 3(1), 2021, 01-10.
- Santos A., De Oliveira R. & Ribeiro F., *Islamic Pedagogy and Digital Learning Tools: a Comparative Analysis of Traditional and Online Learning Environments*, **World Journal of Islamic Learning and Teaching**, 1(1), 2024, 23-29.
- Semilarski H. & Laius A., *Exploring Biological Literacy: A Systematic Literature Review of Biological Literacy*, **European Journal of Educational Research**, 10(3), 2021, 1181-1197.
- Sibomana A., Karegeya C. & Sentongo J., *Effect of Cooperative Learning on Chemistry Students' Achievement in Rwandan Day-Upper Secondary Schools*, **European Journal of Educational Research**, 10(4), 2021, 2079-2088.
- Skinner E. A., Rickert N. P., Vollet J. W. & Kindermann T. A., *The Complex Social Ecology of Academic Development: A Bioecological Framework and Illustration Examining the Collective Effects of Parents, Teachers, and Peers on Student Engagement*, **Educational Psychologist**, 57(2), 2022, 87-113.
- Speechley M., Stuart J. & Modecki K. L., *Diverse Gender Identity Development: A Qualitative Synthesis and Development of a New Contemporary Framework*, **Sex Roles**, 90(1), 2024, 1-18.
- Starr C. R. & Simpkins S. D., *High School Students' Math and Science Gender Stereotypes: Relations with their STEM Outcomes and Socializers' Stereotypes*, **Social Psychology of Education**, 24(1), 2021, 273-298.
- Talan T., *The Effect of Computer-Supported Collaborative Learning on Academic Achievement: A Meta-Analysis Study*, **International Journal of Education in Mathematics, Science, and Technology (IJEMST)**, 9(3), 2021, 426-448. Available online: <https://doi.org/10.46328/ijemst.1243>
- Toma R. B., Yáñez-Pérez I. & Meneses-Villagr  J.  ., *Towards a Socio-Constructivist Didactic Model for Integrated STEM Education*, **Interchange**, 55(1), 2024, 75-91.
- Tseer T., Ngmenkpieo F. & Damwah A. K., *Normalised Heteropatriarchy and Performance Disparity among Male and Female Students in Senior High Schools*, **International Journal of Educational Research Open**, 8, 2025, 100425.
- Tu W., Abidin M. J. B. Z., Zhang F. & Chen W., *Comparison of The Motivation Differences Between Script Teaching Mode and Traditional Teaching Mode for International Business Students in Guangdong Communication Polytechnic*, **Technium Soc. Sci. J.**, 62, 2024, 69.

- Udosen I. N. & Edem S. N., *Assessment of the Academic Performance of SSII Male and Female Biology Students taught using Talent Learning Management Systems (LMS) and those taught with Expository Method*, **Intercontinental Journal of Education, Science and Technology**, 8(1), 2024, 85-97.
- Uralovich K. S., Toshmamatovich T. U., Kubayevich K. F., Sapaev I. B., Saylaubaevna S. S., Beknazarova Z. F. & Khurramov A., *A Primary Factor in Sustainable Development and Environmental Sustainability is Environmental Education*, **Caspian Journal of Environmental Sciences**, 21(4), 2023, 965-975.
- Usman G.B.T., Ali N. M. & Ahmad M. Z., *Effectiveness of STEM Problem-based Learning on the Achievement of Biology among Secondary School Students in Nigeria*, **Journal of Turkish Science Education**, 20(3), 2023, 453- 467.
- Vu N. C., Hooker J. F. & Simonds C. J., *Cooperative, Competitive, or Individualistic? Exploring the Role of Social Interdependence in the Classroom*, **Communication Education**, 70(3), 2021, 247-265.
- Wang J. & Jou M., *The Influence of Mobile-Learning Flipped Classrooms on the Emotional Learning and Cognitive Flexibility of Students of Different Levels of Learning Achievement*, **Interactive Learning Environments**, 31(3), 2023, 1309-1321.
- Wibowo S., Wangid M. N. & Firdaus F. M., *The Relevance of Vygotsky's Constructivism Learning Theory with the Differentiated Learning Primary Schools*, **Journal of education and learning (Edu Learn)**, 19(1), 2025, 431-440.
- Winarni E. W. & Purwandari E. P., *Project-based Learning to Improve Scientific Literacy for Primary Education Postgraduate Students in Science Subject*, **Jurnal Prima Edukasia**, 8(1), 2020, 67-77. Available online: doi:<https://doi.org/10.21831/jpe.v8i1.30618>
- Wrigley-Asante C., Ackah C. G. & Frimpong L. K., *Gender Differences in Academic Performance of Students Studying Science Technology Engineering and Mathematics (STEM) Subjects at the University of Ghana*, **S N Social Sciences**, 3(1), 2023, 12.
- Wu D. & Hu Y., *Construction of New Engineering Talent Training Mode from the Perspective of Innovation Ecology—Optimization and Innovation Path of University and Industry Cooperation Mechanism*, **Journal of Human Resource Development**, 6(2), 2024, 20-27.
- Wu L., Hsieh P. J. & Wu S. M., *Developing Effective E-Learning Environments Through E-Learning use Mediating Technology Affordance and Constructivist Learning Aspects for Performance Impacts: Moderator of Learner Involvement*, **The Internet and Higher Education**, 55, 2022, 100871.

- Wullschleger A., Vörös A., Rechsteiner B., Rickenbacher A. & Merki K. M., *Improving Teaching, Teamwork, and School Organization: Collaboration Networks in School Teams*, **Teaching and Teacher Education**, 121, 2023, 103909.
- Yahaya H., *The Effects of Problem-based Learning on Academic Achievement in Ecology Concepts among Science Education Students in Gusau*, **Glob Acad J Humanit Soc Sci**, 5(4), 2023, 194-199.
- Yeung M. M. Y., Yuen J. W. M., Chen J. M. T. & Lam K. K. L., *The Efficacy of Team-based Learning in Developing the Generic Capability of Problem-Solving Ability and Critical Thinking Skills in Nursing Education: A Systematic Review*, **Nurse Education Today**, 122, 2023, 105704.
- Yongsen L. & Guodong Z., *The Impact of Physical Education on Student Well-Being: A Comparative Study of Traditional and Innovative Teaching Methods*, **Journal of RoiKaensarnAcademi**, 9(12), 2024, 2656-2663.

Website

- Lawal N., *Lagos vs Ogun, Abia vs Anambra: List of States with the better WAEC Results in 7 years*, 2022. Available online: <https://www.legit.ng/education/1487754-lagos-ogun-abia-anambra-states-waec-results-7-years/>

Appendix I
Ecology Achievement Test

Instructions:

In Section A: Please provide an appropriate answer to the following questions

In Section B: Please shade only one answer at a time from the given options

Duration: 45 minutes

Section A
Demographic Characteristics of Participants

School Name: _____

Gender:

Male ()

Female ()

Section B

1. Which of the following is the primary source of energy in an ecosystem?
A) Soil
B) Sunlight
C) Water
D) Oxygen
2. Which of the following is an example of a biotic factor in an ecosystem?
A) Temperature
B) Rainfall
C) Plants
D) Soil pH
3. In a food chain, which organism is usually the producer?
A) Herbivore
B) Carnivore
C) Plant
D) Omnivore
4. Which of the following describes the role of decomposers in an ecosystem?
A) They consume producers.
B) They break down dead organisms and recycle nutrients.
C) They feed on herbivores.
D) They produce oxygen for the system.
5. Which of the following is an example of a mutualistic relationship?
A) A lion hunting a zebra
B) A bee pollinating a flower
C) A tick on a dog
D) A bird eating ticks from a buffalo
6. Which of the following best describes an ecological niche?
A) The physical location where an organism lives

- B) The organism's role in its environment
 - C) The species' diet
 - D) The predator-prey relationship
7. What term is used to describe the gradual and predictable changes in species composition in an area over time?
- A) Ecological succession
 - B) Biodiversity
 - C) Natural selection
 - D) Population density
8. Which of the following terms refers to the maximum number of individuals an environment can support?
- A) Carrying capacity
 - B) Population density
 - C) Habitat
 - D) Reproductive rate
9. The movement of energy through an ecosystem is best represented by which of the following?
- A) Carbon cycle
 - B) Water cycle
 - C) Food chain
 - D) Nitrogen cycle
10. Which of the following represents an abiotic factor in an ecosystem?
- A) Fungi
 - B) Rocks
 - C) Fish
 - D) Algae
11. What is the primary purpose of photosynthesis in plants?
- A) To produce oxygen
 - B) To break down glucose
 - C) To store energy in the form of glucose
 - D) To release carbon dioxide
12. In a pyramid of biomass, which level has the greatest amount of biomass?
- A) Primary producers
 - B) Primary consumers
 - C) Secondary consumers
 - D) Tertiary consumers
13. What type of organism is most likely to be a primary consumer?
- A) Herbivore
 - B) Carnivore

- C) Omnivore
 - D) Decomposer
14. Which of the following is an example of a non-renewable resource in an ecosystem?
- A) Air
 - B) Water
 - C) Soil
 - D) Fossil fuels
15. Which of the following is a characteristic of a stable ecosystem?
- A) High biodiversity and many niches
 - B) A lack of species interactions
 - C) A simple food chain
 - D) Limited competition
16. Which of the following best defines a biome?
- A) A small area where specific species live
 - B) A region with similar climate and vegetation
 - C) The role of a species in an ecosystem
 - D) The total number of species in an area
17. Which of the following is a primary effect of deforestation?
- A) Increased biodiversity
 - B) Decreased carbon dioxide in the atmosphere
 - C) Increased soil fertility
 - D) Loss of habitat for wildlife
18. In an energy pyramid, the energy available decreases as you move up because ____
- A) Energy is used for reproduction
 - B) Some energy is lost as heat
 - C) Energy is stored in dead organisms
 - D) Organisms do not consume enough energy
19. What term is used to describe the relationship between organisms of different species living together in close physical proximity, often to the benefit of both?
- A) Competition
 - B) Commensalism
 - C) Symbiosis
 - D) Parasitism
20. Which of the following cycles involves the process of nitrogen fixation, nitrification, and de-nitrification?
- A) Carbon cycle
 - B) Nitrogen cycle
 - C) Water cycle
 - D) Oxygen cycle

Appendix II
Ecology Achievement Test
Marking Guide

Answer:

1. B
2. C
3. C
4. B
5. B
6. B
7. A
8. A
9. C
10. B
11. C
12. A
13. A
14. D
15. A
16. B
17. D
18. B
19. C
20. B

Appendix III
Instructional Guides for Teaching and Learning
Instructional Guide for Experimental Group A
Lesson Note I
Teaching Ecology using the Team-based Learning Strategy

Topic: Introduction to Ecology

Grade Level: Senior Secondary School (SSS) II

Duration: 2 class periods (90 minutes each)

Learning Objectives:

- Understand the basic principles of ecology and the components of ecosystems.
- Analyze the interactions between biotic and abiotic factors in an ecosystem.
- Apply ecological concepts to real-world scenarios through teamwork and problem-solving.

Presentation:

Content Development	Time (Mins)	Teacher's Activities	Students' Activities
Class Period 1			
Introduction	10	Greet students and introduce the topic of ecology. Provide an overview of the lesson structure and explain the Team-based Learning (TBL) approach. State the learning objectives for the lesson.	Listen attentively to the teacher's introduction. Ask questions for clarification on the TBL structure and objectives.
Individual Readiness Assurance Test (iRAT)	20	Distribute the 10-question multiple-choice quiz based on pre-class readings. Monitor the classroom and assist students as needed. Collect the quizzes after 20 minutes.	Complete the iRAT quiz individually, answering questions related to ecological concepts. Review answers before submitting.

Team Readiness Assurance Test (tRAT)	20	Form teams of 4-5 students and explain the process for the tRAT. Distribute the same quiz for the tRAT. Monitor teams as they discuss questions and come to consensus on answers.	Work collaboratively within their teams to discuss and answer the tRAT questions. Submit the team's answers after reaching consensus.
Feedback and Discussion	15	Review the correct answers to the iRAT and tRAT with the class. Provide explanations for each answer and clarify any misconceptions. Encourage questions and facilitate class discussion.	Engage in the discussion by asking questions or providing comments. Take notes on explanations provided by the teacher.
Application Exercise Introduction	25	Introduce a case study or real-world scenario related to an ecosystem (e.g., the impact of deforestation on local biodiversity). Explain the task for teams: analyze the case study and discuss biotic and abiotic factors, potential ecological consequences, and solutions. Provide guidelines for the analysis.	Formulate questions and begin discussing the case study in their teams. Identify biotic and abiotic factors involved in the scenario. Propose potential ecological consequences and solutions.
Class Period 2			
Team Presentations	30	Facilitate team presentations, allowing each team 5-7 minutes to present their analysis. Encourage the audience to ask questions after each presentation.	Present their team's findings and proposed solutions to the class. Engage with other teams during the Q&A sessions by asking questions or providing feedback.
Class Discussion	15	Lead a class discussion synthesizing the teams'	Participate in the discussion, sharing

		presentations. Ask guiding questions to facilitate deeper understanding and connection to broader ecological concepts.	thoughts and insights based on their presentations and the information provided by other teams.
Peer Evaluation	15	Distribute peer evaluation forms to assess team contributions. Explain the purpose and criteria for evaluating peers.	Complete the peer evaluation forms, assessing their teammates' participation and contributions to the team's work.
Reflective Closing Activity	15	Ask students to write a brief reflection on their learning experience regarding ecology and teamwork. Provide prompts or guiding questions for their reflections.	Write a reflective piece about what they learned during the lessons, how ecological principles apply to their lives, and their experience working in teams.

Assessment:

- 1. iRAT and tRAT Scores:** Evaluate individual and team performance based on readiness assurance tests.
- 2. Team Presentation:** Assess team presentations using a rubric that includes clarity, understanding of ecological concepts, and audience engagement.
- 3. Peer Evaluations:** Review peer evaluations to assess individual contributions and teamwork dynamics.
- 4. Reflective Writing:** Evaluate reflections for understanding and personal connections to ecological concepts.

Appendix IV
Instructional Guides for Teaching and Learning
Instructional Guide for Experimental Group B
Lesson Note II
Teaching Ecology using the Project-based Learning Strategy

Topic: The Impact of Human Activities on Local Ecosystems

Grade Level: Senior Secondary School (SSS) II

Duration: 2 class periods (90 minutes each)

Learning Objectives:

- Analyze the effects of human activities on local ecosystems.
- Conduct independent research and synthesize information from multiple sources.
- Present findings effectively through a chosen medium.

Pre-Class Preparation

Materials:

- Access to research materials (books, articles, online databases).
- Art supplies or digital tools for presentations (e.g., PowerPoint, Canva).
- Rubric for assessment.

Assignments:

Students will be instructed to choose a specific human activity (e.g., deforestation, pollution, urbanization) and its impact on a local ecosystem for their project.

Presentation:

Content Development	Time (Mins)	Teacher's Activities	Students' Activities
Class Period 1			
Introduction to Project	15	Introduce the project topic and explain its relevance to students' lives and the environment.	Listen to the introduction and take notes on the project guidelines.

		Discuss the objectives and expectations for the project. Provide examples of specific human activities that can be studied.	Begin brainstorming potential topics or activities to research.
Project Planning	30	Distribute handouts outlining the project requirements, including deadlines and assessment criteria. Guide students in developing a project timeline and setting personal goals. Encourage students to think critically about their chosen topics and what questions they might want to explore.	Select a specific human activity to research and define the scope of their project. Create a project timeline, outlining key milestones for research, drafting, and presentation. Formulate research questions that will guide their investigation.
Research Phase	30	Provide guidance on effective research strategies, including how to find credible sources and analyze information. Circulate around the classroom, offering support and answering questions as students begin their research.	Conduct independent research using books, articles, and online resources to gather information on their chosen topic. Take notes on key findings, focusing on the specific impacts of the chosen human activity on local ecosystems.
Reflection and Planning for Next Class	15	Encourage students to reflect on their research process and any challenges they encountered. Explain the next class's focus on synthesizing research and preparing presentations.	Write a brief reflection on their research progress and any new insights gained. Prepare questions or areas for clarification to discuss in the next class.
Class Period 2			
Synthesis of Research	30	Provide a mini-lesson on how to synthesize research into clear, cohesive presentations. Discuss different formats (e.g., poster, PowerPoint,	Organize their research findings into a coherent format, selecting the medium for their presentation (e.g., visual

		written report). Offer tips on effective communication and presentation skills.	poster, digital slideshow, written report). Begin creating their presentations, integrating visuals and data as appropriate.
Presentation Preparation	30	Circulate around the room, providing feedback and suggestions as students work on their presentations. Remind students to consider their audience and the best way to convey their message.	Finalize their presentations, ensuring they clearly articulate the human activity's impact on the local ecosystem. Practice their presentations individually or in front of a peer for feedback.
Presentations	30	Facilitate the presentation session, introducing each student and maintaining time limits. Encourage a supportive atmosphere, prompting students to ask questions and provide constructive feedback.	Present their projects to the class, sharing their findings and the impact of their chosen human activity. Engage with peers by asking and answering questions after each presentation.

Assessment:

1. **Project Marking Guide:** Evaluate each project based on clarity of research, depth of analysis, creativity of presentation, and communication skills.
2. **Reflection:** Assess students' reflections on their research process and learning experiences.
3. **Peer Feedback:** Optionally, incorporate peer feedback on presentations to promote engagement and constructive critique.

Appendix V
Instructional Guides for Teaching and Learning
Instructional Guide for Control Group C
Lesson Note III
Teaching Ecology using the Traditional Teaching Strategy

Topic: Introduction to Ecology

Grade Level: Senior Secondary School (SSS) II

Duration: 2 class periods (90 minutes each)

Learning Objectives:

- Define ecology and explain its importance.
- Identify different ecological levels (organism, population, community, ecosystem, biome, biosphere).
- Understand the relationship between organisms and their environment.

Presentation:

Content Development	Time (Mins)	Teacher's Activities	Students' Activities
Class Period 1			
Introduction to Ecology	15	Begin with a brief introduction to ecology, defining the term and discussing its significance in understanding environmental issues. Use a whiteboard or flip chart to write key definitions and draw connections to real-world examples (e.g., climate change, conservation efforts).	Listen attentively and take notes on the definitions and examples presented. Participate in a brief question-and-answer session to clarify understanding.
Lecture on Levels of Ecological Organization	30	Present a structured lecture on the different levels of ecological organization: organism, population, community, ecosystem, biome, and biosphere.	Take detailed notes during the lecture. Engage in a guided discussion, answering questions posed by the

		Use visual aids such as slides or diagrams to illustrate each level, providing examples and discussing how they interrelate. Emphasize key characteristics of each level and its role in the study of ecology.	teacher and contributing to the conversation based on their understanding.
Review of Key Concepts	15	Summarize the key points discussed in the lecture, reinforcing the importance of each level of ecological organization. Distribute a handout summarizing the main concepts for students to keep as a reference.	Review their notes and the handout, ensuring they understand the content. Formulate any remaining questions about the material to discuss in the next class.
Homework Assignment	30	Assign students to read a chapter from the textbook or selected articles related to ecology and its importance. Instruct students to prepare a brief written summary of the key points and any new information they learned from the reading.	Complete the assigned reading at home, highlighting important information. Write a summary that will be discussed in the next class.
Class Period 2			
Discussion of Homework and Key Concepts	30	Begin the class by discussing the homework assignment, inviting students to share their summaries and insights from the reading. Facilitate a discussion to clarify any misunderstandings and reinforce key concepts from the previous class.	Present their summaries to the class, highlighting significant points. Engage in discussions, asking questions and providing input based on their readings.
Direct Instruction on Ecosystems and Biodiversity	30	Deliver a lecture focusing on ecosystems, biodiversity, and the relationships between organisms and their	Take notes during the lecture, focusing on key concepts and definitions.

		environments. Use diagrams and examples of various ecosystems (e.g., forest, desert, aquatic) to illustrate concepts. Highlight the importance of biodiversity and the role it plays in maintaining ecological balance.	Participate in interactive questioning to check their understanding of the material presented.
Class Activity: Quiz on Key Concepts	15	Administer a short quiz covering the material discussed in both class periods. The quiz should include multiple-choice and short-answer questions on ecology and ecological levels.	Complete the quiz independently, demonstrating their understanding of the concepts covered in the lessons.
Conclusion and Reflection	15	Summarize the main points from both class periods and reinforce the significance of ecology in understanding environmental issues. Discuss the importance of continued learning in this field and its relevance to real-world applications.	Reflect on what they have learned about ecology and its significance. Share any thoughts on how the knowledge gained can be applied to real-world environmental challenges.

Assessment:

1. **Quiz:** Evaluate students' understanding of key concepts through a quiz, providing immediate feedback.
2. **Homework Summary:** Assess the quality and depth of the written summaries for understanding and engagement with the material.
3. **Class Participation:** Monitor student engagement during discussions and lectures to gauge their interest and comprehension.

Bio-data

A. Personal Data:

1. **Full Name:** Rebecca Iyabo OGUNRINDE
Address: No 18, Zone 3, Wonderland Estate, Kotopo Abeokuta.
E-mail Address & Phone no: ogunrinde1040@gmail.com, 07032283324
2. **Date and Place of Birth:** 10 April, 1980. Imeko
3. **Nationality:** Nigeria
4. **Marital Status:** Married
5. **No. of Children & their ages:** Four (12, 10, & 6)
6. **Name and Address of Spouse:** Adeniyi James OGUNRINDE
Address: No 18, Zone 3, Wonderland Estate, Kotopo, Abeokuta.
E-mail address & Phone no: ogunrinde1040@gmail.com, 07031090301
7. **Name of Next of Kin:** Adeniyi James OGUNRINDE
8. **Address of Next of Kin:** No 18, Zone 3, Wonderland Estate, Kotopo, Abeokuta
9. **Date of Assumption of Duty in current establishment:** August, 2008
10. **Status on first appointment in current establishment:** Class Teacher
11. **Present position:** Assistant Lecturer
12. **Date of last promotion:** October, 2022
13. **Date of confirmation of appointment:** August, 2008
14. **Department:** Science

B. Educational Background:

1. **Educational Institutions Attended with Dates and Qualification:**
 - i. Romans Catholic Mission Primary School: 1991
 - ii. Queen's School Apata Ibadan: (O'Level Certificate) 1997
 - iii. Ekiti State University, Ado Ekiti (B.sc.Ed) 2015

C. Awards and Fellowships:

D. Work Experience:

- | | | |
|----|---------------------------------|----------------|
| 1. | Primary School Class Teacher :- | 2008 to 2014 |
| 2. | Administrative Officer: - | 2014 to 2018 |
| 3. | Assistant Lecturer:- | 2018 Till Date |

E. Membership of Academic Professional Bodies

1. COEASU FCE Abeokuta
2. Teachers Registration Council

F. Publications:

1. Published Refereed Conference Proceedings: Internet Addition Biology as a Correlate of Biology Students Academic Achievement in Tertiary Institution

G. Major Conferences/Workshops Attended

1. Science and Technology; A Tool for Combating Inflation, Insurgency, and Educational Brain drain in Nigeria. March, 2023
2. Innovative Research and Quality Education for Sustainable Development. October, 2023
3. Re-Contextualizing STEME for Sustainable Global Development. May, 2024

H. Referees:

Dr. Sam-Kayode, C.O

Department of Science Education,
Lead City University Ibadan
08165357640.

Prof. Yara, P.O

Department of Science Education,
Lead City University Ibadan
08034715891.

Pastor Akaraiwe, D.A

Clegy Man, RCCG Ogun Province 26 (APICP CSR).
08034108084

Signature

Date

The University Compliance Certification

This is to certify that this thesis by Rebecca Iyabo OGUNRINDE with the matriculation number LCU/PG/005618 in the Department of Science Education, Faculty of Education, Lead City University, Ibadan, Oyo state is in full compliance with the approved University format and style.

Signature

Date