ENHANCING SECONDARY SCHOOL STUDENTS' CRITICAL THINKING SKILLS AND ECOLOGY ACHIEVEMENT USING PROJECT-BASED LEARNING APPROACH IN MINNA NIGER STATE

BY

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MTech/SSTE/2018/7809

DEPARTMENT OF SCIENCE EDUCATION
FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTERS OF TECHNOLOGY (MTech BIOLOGY EDUCATION) IN DEPARTMENT OF SCIENCE EDUCATION

MAY, 2023

DECLERATION

I OCHIGBO, Faith Ihotu hereby declared that this project titled "**Enhancing Secondary School Students' Critical Thinking Skills and Ecological Achievement Using Project-Based Learning Approach in Minna Niger State**" is my original work and it has not been presented for the award of a degree in any institution or for any other award anywhere. Information from other sources (published or unpublished) has been duly acknowledge.

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Signature & Date

CERTIFICATION

This is to certify that the research entitled "**Enhancing Secondary School Students' Critical Thinking Skills and Ecological Achievement Using Project-Based Learning Approach in Minna Niger State**" by OCHIGBO, Faith Ihotu (MTech/SSTE/2018/7809) meets the regulation governing the award of degree of Masters of Technology (MTech) in Biology Education in the Department of Science Education, School of Science and Technology Education, Federal University of Technology Minna.

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DEDICATION

I dedicated this thesis to God Almighty for his faithfulness, who gave me strength and knowledge in my everyday life to come this far in my research work.

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ABSTRACT

The purpose of this research study was to investigate the effects of project-based learning on senior secondary school students critical thinking skills and academic achievement in ecology in Minna metropolis Niger state. The research design adopted for this research is mixed method explanatory sequential design. Eight research questions were answered and six null hypotheses were formulated and tested at 0.05 level of significance. A total number of one hundred and ninety-four (194) (113 male and 79 female) for the study were used for the study. The sample for this study comprises of four secondary schools selected purposively from twenty-nine (29) secondary schools in Minna, Niger State. The schools were randomly assigned to control and experimental groups. The research instrument Biology Critical Thinking Test Instrument (BCTST), Ecology Achievement Test (EAT) and Interview Question Protocol (IQP). The reliability of the index of the BTCST instruments were 0.81, 0.74, 0.83, and 0.72 respectively while the EAT instrument was 0.77. Data collected were analyzed using Multivariate analysis of variance (MANOVA) and analysis of covariance (ANCOVA) for the quantitative data while Thematic content analysis (TCA) was used to collect qualitative data. The result of the research revealed that project-based learning was more effective in positive development of the students' critical thinking skills and academic achievement level. The findings also revealed that gender has a significant effect on students critical thinking skills and academic achievement. Based on the findings, it was recommended that teachers should use project-based learning to improve the level of critical thinking skills and academic achievement of the students and improve learning process.

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GLOSSARY

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PjBL	Project-based learning
CTS	Critical thinking skill
EAT	Ecology achievement test
BCTST	Biology critical thinking skill test
IQP	Interview question protocol

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Education is pivotal factor when it comes to preparing the next generation to face the ever-changing future, education has an important role in improving the ability and skills of students in the 21st century. The pace of the change in our world is accelerating, and students are required not only to have high ability but also to have skills in various fields. Designing classroom instruction with a 20th century mind set no longer prepares students for future success. The conventional teaching method which characterized the 20th century education is questionable and lacking in providing the necessary knowledge skills needed by the students to survive in the ever-changing society.

To be able to survive, the inconveniences contained in the 21st century, students' need to be equipped with several skills and abilities, such as creative thinking skills, critical thinking skills, metacognitive skills, cognitive ability, scientific attitudes, and knowledge. Erol *et al.* (2016) explain that the competencies needed in the working world are personal and interpersonal competencies. Interpersonal competencies are competencies related to actions, and domains that include methodology and language. Developing critical thinking skills, creative thinking skills, cognitive skills and metacognitive skills are classified as developing personal competencies while developing scientific attitudes is part of developing interpersonal competence. The World Economic Forum also defines the skills that must be possessed by the human resources in the future as cognitive abilities, system skills, complex problem solving, content skills, and process skills (Dimyati, 2018). Hence, the need for these skills to be on the watch in teaching and learning process. In the teaching and learning process, the teachers are responsible for preparing students to be able to compete in the working world.

The development of students' critical thinking skills is essentially required because these skills are what the society today need (Rochmahwati *et al.* 2016). This is because critical thinking skills enable students to solve problems creatively (Mumford *et al.* 2012). According to Facione, (2015a) critical thinking greatly influences the success of one's learning and career. Many definitions of critical thinking were proposed by experts due to the absence of an operational definition such as critical thinking is an art in analyzing and evaluating as an effort to improve thinking independence through good judgment and evaluation (Paul & Elder, 2019). According to Kopzhassarova *et al.* (2016) critical thinking is the ability to find and determine objective ways of receiving information, comparing and analyzing various perspectives, understanding complexity and appreciating differences in answers. Aliakbari and Sadeghdaghighi, (2011) stated that critical thinking skill is important since they are integrated in everyday life. This implies that it is critical for meaningful living in the 21st century.

Mite and Corebima, (2017) opined that critical thinking is one of the skills needed in this century to prepare students for education and work life. Saglam *et al.* (2017) stated that critical thinking skills are high order thinking skills that are obtained after mastering the low order thinking skills. According to Pithers and Soden, (2017) critical thinking is thinking that involves the ability to answer questions through independent search and questioning of knowledge, a sense that knowledge can be challenged, and can present evidence to support arguments. Facione, (2015b) stated that critical thinking is self-regulation in assessing something that results in interpretation, analysis, evaluation, and inference, as well as exposure using evidence, concepts, methodologies, criteria, or contextual considerations that form the basis of decisions.

Murat, (2016) argues that when students think critically, they are encouraged to think for themselves, question hypotheses, analyze and synthesize events, to go further by

developing new hypotheses and testing them against facts. Schneider and Stier, (2015) in their research put forward eight general components for critical thinking. The eight components are: (1) making conclusions through fact-based logical reasoning; (2) gathering information through questions; (3) being open to new evidence that refutes previously believed ideas and beliefs; (4) understanding the problem; (5) using analogies; (6) seeing the problem from more than one side; (7) assessing and interpreting information with an impartial view; and (8) having domain knowledge. In line with the above points, the 21st century learning which really put its emphasis on student-oriented learning requires innovative thinking skill such as critical thinking skill to eliminate challenges faced by teachers (Mishra & Kereluik, 2011).

The challenges faced by teachers in the 21st century is to change the learning paradigm, change students' learning methods, thinking patterns, mindset, and ways of acting in developing creative innovations in various fields, so as to reduce unemployment in Nigeria, especially in global market competition. To face these challenges of 21st century teachers need to improve their competencies, professionalism and the quality of learning (Riyana, 2018). One of the things related to the quality of learning is integrating learning models and learning methods to produce innovation in learning. Hence, it is important that the teaching strategies are well-planned to ensure that the learning goals are met.

To achieve learning goals, various pedagogical approaches have been proposed as the most effective way to engage students in developing a set of thinking skills. These approaches include student-centered learning, active learning, project-based learning (PjBL), and inquiry-based learning (Malaysia Ministry of Education (MOE), 2014). Project-based learning (PjBL) can effectively help students develop critical thinking skills which is one of the key elements of STEM education. Therefore, learning using PjBL is

very appropriate to implement in STEM education at school level (Kasim & Che Nidzam, 2018).

Researches have shown that PjBL is capable of developing student critical thinking skill and also improving student academic achievement. Cakici and Twrkmen (2013) stated that PjBL model has become one of the main learning models as response of school to the challenges of the 21st century. PBLA is a learning model that organizes learning about the project in which students conduct in-depth investigation of a real topic to integrate the knowledge and present the results they learned (Panasan & Nuangchalerm, 2010; Kubiatko & Vaculova 2011). Besides, being able to develop ideas of students to create original solutions, find the available resources, presents the results of information search and evaluate the findings of its own is paramount in developing student's skills (Kubiatko & Vaculova, 2011).

Project-based learning also supports the principles of constructivist in collaboration with other independent and active involvement of student in the learning process (Kwan *et al*, 2012; Cakici & Turkmen, 2013). Apparently because of these concerns different researches have been carried out on the effective use of PBLA in various part of the world. Some of the research carried out using PBLA includes, Kwan & Wong, 2012who carried out a study in Indonesia on effect of PBLA model with KWL worksheet on student creative thinking process in physics problems. In addition, Mustika *et al*. (2016) carried out a study in Indonesia on effect of PBLA learning model on critical thinking skills students learning course design in Geography. Artino (2018) also carried out a study in Thailand on the effect of PBLA on students' English language ability. Additionally, Miller (2019) carried out a study in United States on students' perspectives of PBLA across disciplines, and Bas (2011), who carried out a study in Turkey on investigating the effect of PBLA on students' academic achievement and attitude towards English lessons.

PBLA is a very interesting and motivating approach to students as it increases student involvement and interest in learning, increases student self-esteem and help students understand the meaning of high-level thinking skill (Bell, 2010). PBLA enables students to ask good questions, encourages them to learn through inquiry and do research by working collaboratively (Bell, 2010). Despite the fact that PBLA approach is expected to be able to enhance student's critical thinking skills it is also expected to improve student's academic achievement as well. Nevertheless, there are some factors that influence thinking skills and achievement. This factor is usually gender. According to (Mahanal *et al*, 2017) gender is one factor that can influence ones thinking skills.

Gender is a general term which refers to sexual categories of male and female. Gender is inherently influenced by social and cultural factors that shape psychology and one's role so that it affects how individual think, behave and feel a phenomenon within themselves (Santrock, 2011). Ramdiah and Corebima, (2014) state that the difference on biological growth particularly in term of gender causes significance difference between critical thinking skills of students. Based on research it has been revealed that the difference on gender influences the scores of students critical thinking significantly (Aziz *et al*. 2013). On the other hand (Rachmatullah & Ha, 2019) pointed out that there are differences in cognitive processes of male and female students in solving chemical problems. In the research result of Rizal *et al*. (2019) it was pointed out that the scores of female students critical thinking skills is higher than that of the male students.

In another research it has been reported that female students have higher learning achievement compared to the male students (Vural, 2013). This report was different from the research results conducted (Gok, 2014). It was reported that there was no difference in understanding the concept between male and female student, still the difference was found on the problem solving. Male are superior in problem solving ability than the

female counterpart. In view of foregoing, findings on gender and students critical thinking skills and achievement are inconclusive. Therefore, gender is considered as a moderating variable in this study with the view it could yield important data and contribute empirical findings on the effect of PBLA on critical thinking skills.

1.2 Statement of the Research Problem

The challenges of the 21st century require the mastery of some set of skills which enable one to face the global labor market competition. These skills that must be possessed include critical thinking and problem-solving skills, creativity and innovative skills, collaboration and communication skills. Lau (2011) pointed out that in this 21st century, students need to possess the thinking skills that can assist them in making strong decision and live a meaningful life. Kharbach, (2012) stated that the paramount thinking skill that is strongly needed in the 21st century is critical thinking skills. However, the conventional classroom instruction does not seem to help learners acquire these thinking skills. Hence there is need for an alternative instructive approach that will help learners acquire CTS.

The West Africa Examination chief examiner report of 2015-2020 reported that the persistent decline in student's performance in science is as a result of lack of materials for practical lesson, lack of content knowledge by teachers, ineffective teaching methods and teacher centered method used by teachers among others (Okeke, 2011). Therefore, to improve the performance of students in science especially in Biology, a more engaging teaching method should be employed by teachers. Gerard *et al.* (2022), noted that teacher centered method does not promote skill acquisition, objectivity and critical thinking ability among students. Therefore, there is need for a more activity oriented, learners centered and innovative approach that can assist biology achievement. One of these approaches is PBLA, it has the following advantages which includes; (1) Actively

engaging students through hands on activities; (2) it is learners centered; (3) it provides opportunity for students to develop complex skills such as higher order thinking, problem solving, collaborative and communicative skills; (4) it improves students attitude towards education; (5) it provides opportunity for students to engage deeply with the target content bringing about a focus on long term retention; (6) it connects students' academic situation with real world; 7) it provides educators /teachers insights into students learning habit. Knowing the benefits associated with PBLA, it is to be understood that PBLA is not the ultimate goal for teaching instruction, but it is a pragmatic way to reach the goal which is to prepare students for the life in the 21st century (Lenz, 2015).

In most of the literature review, most studies were carried out on tertiary education and the fields are mostly English, Math's, and specific branch of physics. Furthermore, the study is mostly carried out on the areas of student's achievement, student motivation student's ability and perception of students on the implementation of PBLA. Besides, previous study was mostly carried out in other parts of the world such as Turkey, Indonesia, Malaysia, Thailand and United state where as only few or no study have been carried out in Nigeria. There seems to be limited studies that compare PBLA and Critical thinking skills in Ecology. Hence, the motivation to conduct this study. Consequently, this research will therefore experiment the use of PBLA approach in enhancing students critical thinking skills that will help students succeed in the 21st century. Based on the explanation given above, it is on this ground that the researcher aims to ascertain the effectiveness of using PBLA approach in teaching senior secondary school students Ecology to enhance student's critical thinking skills and improve student's achievements in Minna metropolis of Niger.

1.3 Aim and Objectives of the study

The aim of this study is to determine the effect of project-based learning approach in enhancing critical thinking skills and achievement among secondary school biology students in Minna Metropolis Niger state. Specifically, the study will'

1. Determine the main effects of PBLA on secondary school students' critical thinking skills.
2. Explore how secondary school students acquire critical thinking skills.
3. Examine the main effect of gender on secondary school student's achievement in ecology.
4. Examine the interaction effects of the independent variables and gender on critical thinking skills.
5. Determine the main effects of PBLA on secondary school student's achievement in ecology.
6. Explore how secondary school students learn Ecology.
7. Determine the interaction effects of independent variable and gender on secondary school student's achievement in ecology.
8. Examine the main effect of gender on secondary school student's critical thinking skills.

1.4 Research Questions

The study will be guided by the following research questions:

1. What is the difference in the mean score of secondary school students critical thinking skills taught Ecology using PBLA and Lecture method.
2. How does secondary school student acquire critical thinking skills when taught Ecology using PBLA?

3. What is the main effect of gender on secondary school student's achievement in Ecology?
4. What is the interaction effect of the independent variables and gender on critical thinking skills?
5. What is the main effect of PBLA on secondary student's achievement in Ecology?
6. How does secondary school students learn Ecology?
7. What is the interaction effect of independent variable and gender on secondary school student's achievement in Ecology?
8. What is the main effect of gender on secondary school student's critical thinking skills?

1.5 Research Hypotheses

The following null hypotheses were formulated and would be tested at a 0.05 level of significance:

1. There is no significant main effect of PBLA on secondary school students' critical thinking skills.
2. There is no significant main effect of gender on secondary school student's critical thinking skills.
3. There is no significant interaction effect of the independent variables and gender on critical thinking skills.
4. There is no significant main effect of PBLA on secondary student's achievement in Ecology.
5. There is no significant interaction effect of the independent variable and gender on student's achievement in Ecology.
6. There is no significant main effect of gender on secondary school student's achievement in Ecology.

1.6 Significance of the Study

The findings of the study will be of tremendous benefits to secondary school students, secondary school Biology teachers, curriculum planners, examination bodies, Government, school administrators and future researchers.

The findings of the study will help students to participate actively in the classroom and promote meaningful and long-lasting learning of student on the topic. It will also help student to transfer their learning to daily life in science and also contributes to students' academic achievement b improving student's higher order thinking skills such as critical thinking, planning problem solving and creativity.

The findings of the study will give Biology teachers the opportunity to teach Ecology using PBLA as an instructional approach. The use of PBLA will also help teachers to improve the teaching and learning of ecology and also see the need to develop new and effective methods of teaching biology effectively.

This study will help curriculum planners/developers and designers to design programs and syllabus that will emphasize the effective use of project-based learning approach in biology.

The findings of the study will also benefits examination bodies like West African Examination Council (WAEC) and National Examination Council (NECO) to help them include critical thinking questions and problem-solving questions in their practical works in biology.

The Government will also benefit from the study as it will offer a more solid base for Nigerian students and also provide such students with more options in Science and Technology which is the hallmark of civilization.

The school administration will benefit from the results of the study. This is because less effort will be needed to engage the students in learning biology in a manner that will help

students produce better result and this is obviously the expectation of the school for the students to excel academically.

The findings of the study will serve as theoretical benefits to researchers as it will provide a useful research evidence for the need to use PBLA approach in teaching ecology and other biology concepts in secondary school. The findings of the study will be published online, presented in a conference and stationed in the library for researchers and others to gain access to it.

1.7 Scope of the Study

The scope of the study covered the use of project-based learning approach in enhancing secondary school students critical thinking skills and ecology achievement in Minna. Geographically the study was restricted to Minna Metropolis. Niger State Minna is a large place in the region of Nigeria with a population of approximately 291,905 people and is one of the largest places in Niger state. The city is a fast-developing urban center in North-Central Nigeria. It is located between Latitudes 3.20^0 East and Longitude 11.30^0 North and lies wholly with physical and cultural zone of transition described as "middle belt of Nigeria". Kaduna and Federal Capital Territory border the state to both North-East and South-West respectively. Minna has a total land area of 74,344km^2 wide and it is approximately 8% of the land area of the country. The distance from Minna to Nigeria's capital (Abuja) is approximately 121km/75mi &as the crow flies).

Four homogeneous residential densities of low, medium and high were recognized in Minna. These residential areas are characterized by social, economic, and physical patterns. The city of Minna is the administrative Capital of Niger State in Nigeria.

Therefore, the study area is Bosso and Chanchaga Local Government Area of Niger State SSII Biology students were sampled for the study. The study was also limited to the use of three instrument to ascertain the effectiveness of Project-based learning approach on

students critical thinking skills and academic achievement. The study lasted seven(7) weeks.

1.8 Operational Definition of Terms

The terms below were used in this study and the following are the meaning as it concerns this work:

Achievement: Achievement is the gain in Knowledge of SS1 students as a result of taking part in learning of Ecology using PBLA. Therefore, achievement is also regarded as a dependent variable in this study.

Critical thinking skill (CTS): A critical thinking skill is one of the skills needed in this century to prepare student for education and work life. Therefore, critical thinking skill is seen as a dependent variable in this study.

Ecology: Ecology is the branch of biology that studies the interactions among organism and their biophysical environment, which include both biotic and abiotic components. Therefore, ecology is the instructional content in this study.

Gender: Gender refers to sexual categories that are male and female. Therefore, gender in this study is regarded as a moderating variable.

Conventional teaching approach: Conventional approach is also referred to as traditional approach of teaching. It is the teaching using chalk and Board for teachers and pen and paper for students.

Project-based learning (PBLA): PBLA is a learning model that organizes learning about the project in which students conduct in-depth investigation of a real topic to integrate the knowledge and present the results they learned. Hence, PBLA is seen in this study as an independent variable.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

According to Camp (2021) he defined conceptual framework as a structure that the researcher postulate to be the best in explaining the natural progression of the phenomenon to be studied. In a statistical perspective, conceptual framework illustrates the relationship between the main concepts of a study. Grant and Osanloo, (2014) stated that conceptual framework is arranged in a logical structure to help provide a picture of how ideas in a study relate to one another. This picture makes it easier and clear for the researcher to easily specify and define the concepts within the problem of the study (Lenz, 2015).

In the current study, conceptual framework is regarded as a visual display or pictures that is arranged logically to assist the researcher explain how concept of the study relates to one another. The conceptual framework adopted for the study is premised on the fact that PBLA would translate to enhanced critical thinking and achievement of students with gender acting as the moderating variable. For the current study, PBLA model was adopted and 4 critical thinking sub-skills and achievement were expressed in terms of multiple-choice questions. Gender been the moderating variable was expressed in terms of sex (Male and Female). Figure 2.1 presents the diagrammatic representation of the conceptual framework.

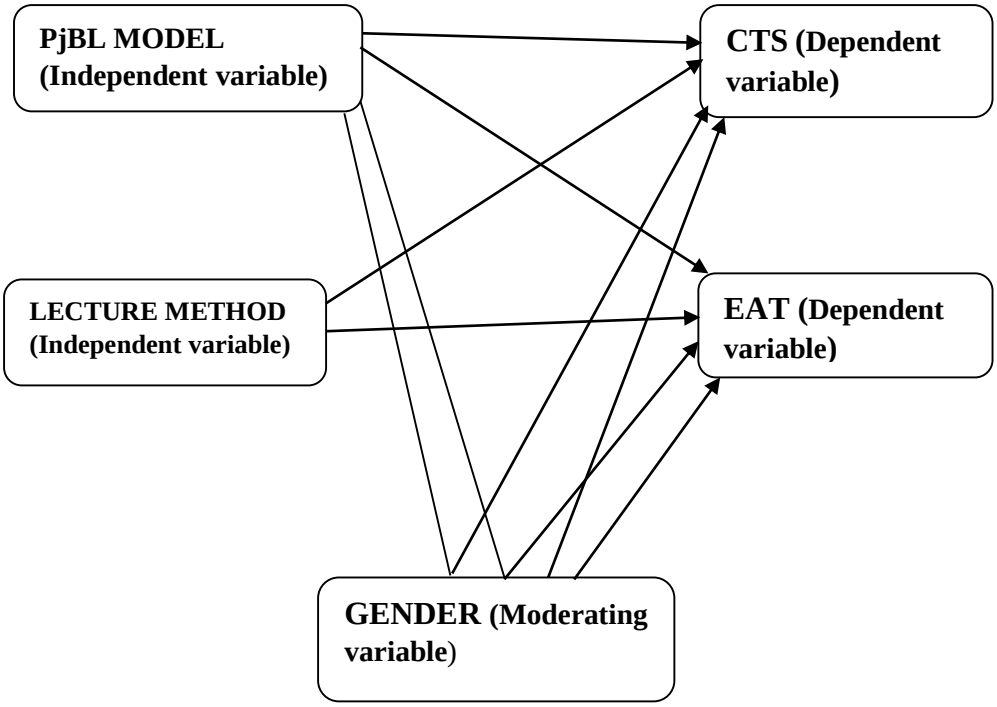

Figure 2.1: Conceptual Framework of PBLA.
Source: The Researcher (2023).

Figure 2.1 shows the conceptual relationships between the major valuables in this study. The independent variables are the PBLA and lecture method which will be manipulated to measure its effect on the dependent variable. The dependent variables are critical thinking skills and ecology achievement. The CTS is made up of four sub sections or sub-skills which include Inference, Analysis, Interpretation and Evaluation. Similarly, gender (male and female) is the moderating variable in this study. The interaction between the moderating variable and the independent variable on the dependent variable will be determined. Finally, gender will help the researcher to determine which of the independent variable is gender friendly**.**

2.1.1 Science Teaching and Learning in Nigeria

Science teaching and learning has been and would continue to be of enormous importance because of the central role it plays in the world's current technology development in the

21st century and its ability to explain many natural occurrences. It is the soul of the prosperity of a nation and it is an economic and technological development as well as enriching the quality of an individual's life and the society. Science, as a school subject, has over the years gained prominence in the school curriculum not only in Nigeria but in the world at large. In the last five decades, the world has witnessed science curriculum innovations and several changes in the teaching and learning of science in different levels of education. (Ajaja & Eravwoke 2010). The objectives of teaching and learning science includes: to acquire the skills of scientific method; Knowledge of science academic discipline; having clear explanations for societal issues through increasing interest in science literacy and societal goals; for personal needs and for career awareness (Ajaja & Eravwoke 2010). The science subjects that are taught in Nigerian schools include Biology, Chemistry, and Physics.

The National Policy on Education in the National curriculum for secondary schools stated specific objectives to be achieved by each subject curriculum. Most of the distinct characteristics of science are observation, experimentation, and discovery. It provides the development of skills needed by students such as asking questions, making investigations, making evaluation, making hypothesis, making decisions and inference of results of experiments to students (Acikgoz *et al.* 2022). The effectiveness of science teaching and learning largely depends on the classroom teachers. They constitute the most important agent in the ongoing exercise to revolutionize the teaching and learning of science. According to Acikgoz *et al.* (2022) science Teachers have the potentials for enhancing the quality of education by bringing life to the curriculum and inspiring student's curiosity as well as hands-on learning.

The alarming rate of poor performance in science subjects coupled with the low educational standard in the country are parts of the major reasons why most students shy

away from the study of science. This negative attitude has encouraged poor performance and low participation of students in the science subjects like physics, chemistry and biology. All these problems mentioned above have been conclusively blamed on science teaching and learning. Science serves as foundation for meaningful understanding of advanced scientific theories and principles because the bulk of content of the science curricular is descriptive, where the student is meant to learn many basic concepts like energy, matter, force, ecology and measurement. Previous studies have revealed that science teaching has been facing problems from different angles ranging from the learner, the teacher, the school, the government and even the parents.

In Nigeria today, meaningful science teaching and learning is needed to enhance the accelerating development in the 21st century. Over the last two decades, there have been repeated calls for reforms and innovations aimed at improving science teaching and learning. Omorogbe & Ewansiha, (2013) suggests that there are issues in science teaching and learning that needs to be improved upon. Aina, (2013) also confirmed the presence of unqualified science teachers in secondary schools as one of such issues in science teaching and learning. It is obvious that science is the major determinant in student's success because; learning science brings about new ideas and innovations that help to develop a nation. But regrettably, the teaching and learning of science in Nigerian schools cannot be said to be effective because of the level of poor performance of the students.

As opined by Omosewo, (2009) this poor performance result from various problems such as many teachers handling the science subjects in most of secondary schools in Nigeria specializes in science, not in science education. Therefore, these teachers lacked appropriate instructional strategies for teaching and often used traditional approach of teaching. Inadequate teaching methods have been one of the problems of science education in Nigerian schools.

Effective teaching only occurs when students learn and achieve many scientific goals and not just being able to memorize scientific knowledge (Omoifo, 2012). During an effective learning, students develop conceptual understanding and thinking skills which helps them change their intuitive and to incorporate scientific concepts into their daily activities. Ayodele (2018) identified the use of inappropriate and non-effective teaching methodology as a major factor hindering students understanding and achievement in science.

The teaching and learning of science do not require theoretical and lecture approaches. Many teachers teach science as an abstract thereby making science lessons boring and students find it difficult to grasp some scientific concepts and skills. Abdullahi (2014) and Achor *et al.* (2014) observed that most teachers emphasize theory rather than practical aspects of science subjects and most of them lack adequate knowledge of the subject matter and the competence to deliver. In addition, they stressed that teaching science have been reduced to a descriptive exercise through the use of lecture method and very little inquiry. Science teachers should make efforts to ensure adequate and effective teaching. Such efforts include using the right teaching methodology.

Given to the proceeding, traditional approach of teaching is no longer an effective method of teaching. Innovations of various teaching methods that encourages active learning is the only way to engage students on a level beyond knowledge and understanding. Therefore, to reach higher orders of scientific literacy, teachers must engage students not only in explorations of the history and theory that represents science, but the processes, context, and practices as well. One of the important approaches that could adequately engage learners in processes, context, and practice of science similar to what STEM professional practice in real life is Project-based Learning (PBLA).

2.1.2 Project-based learning

Project-based learning (PBLA) is an old idea that has gained new life as educators seek ways to provide meaningful opportunities to personalize the curriculum, engage students more fully in their learning, and foster active connections in the society. Historically, project-based learning is associated with both Dewey (1897) and Kilpatrick (1918) author of "The Project Method" ideas were spread widely among teachers and administrators during the progressive education movement but have been significantly revised since. Initially, John Dewey promoted the idea of "learning by doing". The view of this two men differed in the details, in that, Kilpatrick was a whole-hearted advocate for student initiated designed and directed projects.

On the other hand, Dewey enumerated his belief regarding education and was of the opinion that the teacher is not to impose certain ideas or to form certain habits in the child. Dewey believes, in the so-called expressive or constructive activity as the center of correlation (Dewey 1897). Dewey felt strongly that the teacher had a stronger role to play in the fostering of cognitive growth, and should take a leading role in the development of the project. Educational research has advanced this idea of teaching and learning into a methodology known as Project-based Learning.

Project-based learning has been defined by so many scholars in many ways and there is no consensus in the definition of PBLA. PBLA has been referred to as a "model", "approach" or a "technique", or as "learning" or "teaching". Project-based learning according to Schwalm and Tylek (2012) Project-based learning (PBLA) is a model of instruction that exposes students with real life, multidisciplinary problems that require critical thinking, hands on activities and collaboration (Jamali *et al,*. 2017)

Buck institute define PBLA as a systematic pedagogy that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic question and carefully designed product and task. Dalimonte, (2013) define project-based learning as a student-centered approach that engages students as they use the inquiry process as they are given a real-world situation or problem to solve while also being aligned to content standards. In fact as long as there is a tendency that the teachers do not have time to develop a learning device that is capable of integrating the issues in real life by planting a character that can improve critical thinking skills of student in defining the problem, taking action to get findings, taking decisions and evaluating issues in real life is also a sensitive issue and it contains a moral dilemma, which is supposed to be a valuable learning resource for the character development of students in school (Duran & Sendag, 2012).

Sahin and Top (2015) pointed out the goal of PBLA is make students become aware of the connections between the academic knowledge and its applications in real life while gaining a deeper understanding of concepts. The genesis of a PBLA is inquiry, in a project-based learning environment, the focus in the classroom shifts from teacher led instruction to student-led instructions. The students become the navigators directing their learning through the inquiry process and the development of project-based learning experiences. The teacher becomes more of a facilitator as the focus in the classroom moves from the instructors teaching the content to students learning the content through the inquiry process and problem solving (Dalimonte, 2013). The instructor provides the students with a list of guidelines, a timeline, and helps them create a plan of action for the project (Coyne *et al*. 2016). The students will decide how they will solve the project-based learning project through the use of the inquiry process. Due to the nature of project-based learning, the students may arrive at a solution which is not an area of expertise for

the instructor (Mann *et al.* 2021). These situations create discussion opportunities and the possibility of a new and exciting solution to the problem (Mann *et al.* 2012). Thus, creating a learning environment that is conducive and exciting for learners.

The main focus of PBLA is an emphasis on students having autonomy to make decisions about the direction of their project (Boss *et al.* 2015). PBLA begins with a student- driving question and uses an integrated curriculum approach to investigate the question, or problem. In this way the teacher facilitates the process but the learner is in the 'driver's seat' and is guided through each step of the process by the teacher (Bell, 2010). Rather than research a topic and report back on known facts, the PBLA approach requires learners to build on their pre-existing knowledge to construct new knowledge and think critically, this results in deeper learning and understanding (Bell, 2010; Boss *et al*, 2015; Krauss & Boss, 2013). PBLA requires careful design in order to promote meaningful learning. The project needs to be relevant and have meaning for the student with a clear educational purpose (Larmer, 2014).

The most essential elements of PBLA include the development of a significant, authentic, driving question that is connected to the real world (Larmer, 2014). This leads the student to develop a challenging and sustained inquiry to encourage them think deeply and critically about the knowledge and understanding that they gain (Boss *et al*. 2015). The authentic aspect is important as it gives the opportunity for students to engage in real-world contexts that are of personal interest and concern (Boss *et al*., 2015). It should be student driven, allowing for student choice and promote the social construction of knowledge, communication and collaborative skills, and self-management (Bell, 2010; Larmer, 2014). Finally, the process should include formative feedback from peers and adult mentors to promote reflection and self-assessment that helps students to refine their projects and produce high quality end products (Larmer, 2014). In PBLA there should be

a final outcome which could be a product (artifact), performance, or action produced that demonstrates the students' new understandings (Helle *et al.* 2016). Students can then publicly present their work, which imparts a sense of pride and develops presentation and communication skills (Boss *et al*. 2015).

An important factor to effective project-based learning is the role of the teacher in how they create meaningful and challenging project environments for the students. PBLA may require some reframing of thinking relating to the level of teacher control in the classroom. However, this does not mean an abdication of responsibility for learning outcomes as teachers have an important role in guiding and coaching students to help them navigate their way through the various stages of the project. This is achieved by the teachers' adding series of support to enhance the students' learning and utilizing a variety of instructional strategies. This includes giving formative feedback, supporting skill acquisition, and developing self-assessment ability (Helle *et al*. 2016; Krajcik & Shin, 2014; Krauss & Boss, 2013; Boss *et al.* 2015).

Kizkapan and Bektas (2017) suggested the use PBLA to the dimensions of the concrete procedural knowledge and skills, thus encouraging critical thinking skills of student to produce a work context. Research has demonstrated that students who are involved in project-based learning classroom gets higher scores than students in traditional classroom (Blumenfeld, 2016). According to Baş, (2011) in his research he stated that project works bring opportunities for students to promote their achievement. Moreover, these works enable students to work together in a real- world environment by collaborating on a task. Also, in the research conducted by Kizkapan and Bektas (2017) he reported that PBLA increases students' academic achievement as well as their critical thinking skills. The narrative featured in this paper is perhaps more illustrative of Dewey's point of view, as it demonstrates a high-level involvement of teachers in helping students build bridges

towards a truly personalized curriculum. Although, PBLA and other student-centered and inquiry-based approaches have historically encountered resistance and criticism by those who emphasize the importance of students' developing specific content knowledge in traditional subject areas (Loveless, 2013). However, PBLA and other instructional approaches that emphasize deeper learning and the development of skills needed for success in school, civic life, and career have become increasingly popular and should be in cooperated in the school curriculum (Huberman *et al.* 2014). In view of the importance of PBLA, it is important to highlights its characteristics.

2.1.3 Characteristics of project-based learning

Project-based Learning (PBLA) is a learning method through which the learners gain and develop higher order thinking skills such as problem solving and critical thinking while eliciting information from personal real-life experiences and acquiring determinate knowledge about their own learning (Wadani & Khan, 2014). It varies from classroom-to-classroom instruction but often characterized by the following:

1. **PBLA projects are central, and curriculum structured:** Thomas (2000) stated that PBLA projects are central and not peripheral to the curriculum. In PBLA, the project is the central teaching strategy. Students encounter and learn the central concepts of the discipline through the project. There is instance which project work follows traditional instruction in such a way that the project serves to provide illustrations, examples, additional practice, or practical applications for material taught initially by other means (Thomas 2000). However, in these application projects are not considered to be instances of PBLA, according to this criterion. Second, the centrality criterion means that projects in which students learn things

that are outside the curriculum ("enrichment" projects) are also not examples of PBLA, no matter how appealing or engaging.

2. **PBLA is characterized by Student centered learning:** The focus of the project remains grounded curriculum that must comply with the content standards and basic competencies. The PBLA starting from depth questions to be framed and is part of the learning curriculum called with questions within the scope of the curriculum. The project involves the assessment process with a variety of assessment techniques. The project involves tasks and activities within a specific time period. The project relates to real life (contextual). Students demonstrate their knowledge and skills through the performance of the work published, presented, or displayed.
3. **PBLA focused on driving questions or problems that drive students to encounter the central concepts and principles of a discipline:** Project focuses on "questions or concerns" that could encourage students to strive to obtain concept in certain field. This is very essential in in PBLA. The definition of the project must be crafted in order to make a connection between activities and the underlying conceptual knowledge that one might hope to foster (Barron *et al* 2018). The link between conceptual knowledge with real activity through the asking of questions or by providing definition of the problem in a weak form so that this can increase student's motivation to foster independence in learning tasks (Loveless 2013).
4. **PBLA involve students in a constructive investigation:** An investigation is a goal directed process that involves inquiry, knowledge building, and resolution. Investigations may be design, decision-making, problem-finding, problem-solving, discovery, or model-building processes. But, in order to be considered as

a PBLA project, the central activities of the project must involve the transformation and construction of knowledge on the part of students (Bereiter & Scardamalia, 2009). If the central activities of the project represent no difficulty to the student or can be carried out with the application of already-learned information or skills, the project is an exercise, not a PBLA project. This criterion means that straightforward service projects such as planting a garden or cleaning a stream bed are projects, but may not be PBLA projects.

5. **Projects are student-driven to some significant degree:** PBLA projects are not, in the main, teacher-led, scripted, or packaged. Laboratory exercises and instructional booklets are not examples of PBLA, even if they are problem-focused and central to the curriculum. PBLA projects do not end up at a predetermined outcome or take predetermined paths. PBLA projects incorporate a good deal more student autonomy, choice, unsupervised work time, and responsibility than traditional instruction and traditional projects.
6. **In PBLA the projects are realistic:** Projects embody characteristics that give them a feeling of authenticity to students. These characteristics can include the topic, the tasks, the roles that students play, the context within which the work of the project is carried out, the collaborators who work with students on the project, the products that are produced, the audience for the project's products, or the criteria by which the products or performances are judged. Gordon and Brayshaw (2008) makes the distinction between academic challenges, scenario challenges, and real-life challenges. PBL incorporates real-life challenges where the focus is on authentic problems or questions and where solutions have the potential to be implemented. Accordingly, this characteristic above covers research-related articles on problem-based learning," "expeditionary learning," project-based

learning," and "project-based instruction". The review on these characteristics is focused primarily on research conducted at the secondary level.

2.1.4 Models of PBLA

Just as there are different definitions of PBLA so also is that of models of PBLA. PBLA is a pedagogical method that has several features which includes: authentic assessment of content, explicit objectives, communicative and collaborative learning, final product, hands on learning, problem solving, decision making, challenging problem with complex task, innovation of ideas, realistic product to real life problem, driving question, formative feedback, student directed learning, and teacher facilitated (Oktaya & Oktaya, 2017; Densita *et al.* 2017; Celik *et al*. 2018; Boss *et al,* 2015; Bas, 2011; Bell, 2010). So many scholars in education have used different models in different level of teaching.

Taharu *et al*. (2019) develop a four-phase model for micro biology student in the university which include; planning – acting – observing – reflection. Aldabus (2018) in his study develop a six (6) phase model of PBLA which include; Introduction and discussion of the topic – challenging problem – students voice and choice – presentation – evaluation – feedback and revision. Hanif *et al*. (2018) developed a five (5) phase model used in junior secondary school mathematics namely; preparation - implementation – presentation - evaluation - correction. Kizkapan and Bektas (2017) implemented five (5) phase model for student in 7^{th} grade namely; identifying the problem – investigating the problem – project plan – presentation – evaluation.

Furthermore, Jamali *et al*. (2017) develop a model which has seven (7) phases namely; Identifying a growing problem - formulation of ideas - creating working drawings - make estimate of production - the production process - carrying out product testing - evaluating the product this model was used for senior secondary school in welding practice. Albritton

and Stacks (2016) implemented a seven (7) phase model used for pre service teachers in the tertiary level which include; design the plan - align standards - build culture - manage activities - scaffold student learning - assess student learning - engage and coach. Erdogan and Bozeman (2015) in their study used a four (4) phase model which includes initiating – management - deliverables - assessment.

Also, in the study of Mihardi *et al*. (2013) the phases employed include; describe the ecosystem - define the problem - research the problem - understand stakeholders interest - determine possible solution – develop a plan – implement the plan – summarize, evaluate and reflect this model was used for physics student in secondary level. Bell (2010) in her study employed six (6) phases of PBLA for middle school student which include; engaging problem – research the problem – designing the project – presentation – evaluation –reflection.

In this study the researcher adapted the model proposed by Bell (2010) which amounted to a Seven (7) phased model namely; Initiating the topic - engaging the problem – investigating the problem – ascertain possible solutions – design the project – presentation of the project – evaluation. Based on the results of previous research, this model shows authenticity and also supports the addition of explicit critical thinking instruction to be purposefully incorporated into the science teaching and learning.

2.1.5 Critical thinking skills

Living in the 21st century requires higher thinking skills such as critical thinking, creative thinking, problem solving, Higher-order thinking, analytical thinking and evaluation (Riechman & Simon, 2013; Kalelioglu & Gulbahar, 2014). Thinking is an activity in which an individual search of a proper answer, filtering out various kinds of data or information, solve problems, and make decision (Zane, 2013). Critical thinking is used to

pass judgment on information, explain the reasons, and to solve the problem of the unknown so that each individual is able to understand any content or information on a particular thing (Zane, 2013; Thomas, 2011). According to Yildirim and Özkahraman (2011) the process of critical thinking is to find, obtain, evaluate, analyze, synthesize, and conceptualize information and the results of thinking activities are been used to solve problems. Critical thinking includes skills in conceptualizing, applying, analyzing, synthesizing, and evaluating information gathered from, or generated by observation, experience, reflection, reasoning, or communication as a guide to belief an action, evaluating information to reach an answer or conclusion (Peter, 2012; Al-mubaid, 2014).

Given the complex nature of critical thinking skills, researchers use diverse concepts to define critical thinking. Critical thinking is one of the levels of higher-order thinking other than creative thinking, problem-solving skills, and decision-making and has gain a lot of attention in recent time to help students survive in 21st century (Firdaus *et al.* 2015). Fisher (2011) defines critical thinking as a skilled and active interpretation and evaluation of observation and communication, information and argumentation. According to (Peter, 2012; Lunenburg, 2011) Critical thinking is a process that occurs because of an understanding of the various information that is integrated through learning skills. Because critical thinking occurs through learning skills, it requires a thinking process that requires the ability of analysis, synthesis, and evaluation.

According to Reed and Kromley (2011), critical thinking is the ability and tendency to analyze complex issues and situations, recognize and evaluate assumptions and alternative points of view according to acceptable criteria, make conclusions, draw reasonable conclusions based on accurate information, make interdisciplinary connections, and transfer insights to new contexts. Critical thinking is define as a cognitive skill that determines how well a person collects, processes, and uses information

to identify the best way to achieve goals or navigate complex situations. Given the above definition, it can be concluded that critical thinking is a systematic, complex intellectual process, involving various attitudes and skills, accompanied by a process of analyzing and evaluating within the framework of making improvements. Critical thinking as an intellectual process involves the activities of attitudes, knowledge, and skills. The main activities in critical thinking are analysis, evaluation, and argumentation (Butterworth & Thwaites, 2013; Novella, 2012). A critical thinker will evaluate and then deduce something based on facts to make a decision (Novella, 2012).

Paul and Elder (2014) states that, through critical thinking, one is able to gain knowledge, understanding, insight, and skills in specific body content. Critical thinking has various elements. Paul and Elder (2014) believes critical thinking mean: every thought has a purpose; looking for new things; find solutions; use data; consider various things, always based on information; utilize the available evidence; and based on concepts and ideas that result from a learning process; contain conclusions and give meaning; and has implications and consequences. Understanding the main activities and critical thinking elements provides conclusions that critical thinking is systematic steps in seeking information, processing, analyzing, and synthesizing that information so that it becomes a conclusion or benefit according to the objectives set. The process involves a variety of intact viewpoints as a component of critical thinking.

The component of critical thinking involves high-level thinking (Duplass & Ziedler, 2012; Wong, 2017). According to Bloom's learning taxonomy which was revised by Anderson and thought scientifically. Anderson and Krathwohl (2011) divides the taxonomy of learning into the knowledge dimension and dimensions of cognitive processes. The knowledge dimension consists of factual knowledge, conceptual knowledge, procedural knowledge, and meta-cognitive knowledge. The dimensions of

the cognitive process consist of remembering, understanding, applying, analyzing, evaluating, and creating. As cognitive skills, critical thinking reflects the ability of interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 2015b). However, for the purpose of this study the researcher defined critical thinking within the frame work of revised bloom's taxonomy (Facione 2015a).

2.1.6 Critical thinking instruction

Many researchers and educators have maintained the importance of developing critical thinking in science, while acknowledging different teaching instruction (Ch 2014). Determining what instructional method to apply remains a challenge. Behar-Horenstein and Niu (2011) reviewed 42 studies on critical thinking instruction identifying mixed results from similar interventions. The premise that critical thinking is to knowing as listening is to hearing implies that critical thinking is a learned skill that must be developed, practiced, and continually integrated into the curriculum to engage students in active learning (Kong *et al*., 2014). To support this premise, focused attention needs to be placed on the application of content, the process of learning, and methods of assessment. In terms of the application of content, teaching techniques that promote memorization (short-term knowledge) do not support critical thinking.

Instruction that supports critical thinking uses questioning techniques that require students to analyze, synthesize, and evaluate information to solve problems and make decisions rather than merely to repeat information. Because critical thinking is a mental process that requires students to think about their thinking and about improving the process, it requires students to use higher-order thinking skills not memorize data or accept what they read or are told without critically thinking about it (Scriven & Paul, 2018; Tempelaar, 2016). Therefore, critical thinking is a product of education, training,

and practice. To link critical thinking skills to content, the instructional focus should be on the process of learning. How will the students *get* the information? Celuch and Slama, (2019); Daz-Iefebvre, (2014); Kang and Howren, (2014) in their research supports the presumption that lecture and memorization do not lead to long-term knowledge or the ability to apply that knowledge to new situations. Traditional instructional methods use too many facts and not enough conceptualization, too much memorizing and not enough thinking. Therefore, lecture and rote memorization do not promote critical thinking. Instructional strategies that employ students' higher-order thinking skills lead to improved critical thinking skills (Duplass & Ziedler, 2012; Wong, 2017).

Additionally, assessments should emphasize thinking rather than facts (Ennis, 2009). Quizzes, graded assignments or tests should become intellectual challenges rather than memory recall (Schafersman, 2011). Subjective tools such as essay questions and case studies require students to apply their knowledge to new situations and are better indicators of understanding than objective true/false or standardized multiple-choice assessments. However, instructors can create multiple-choice questions that require critical thinking. For example, a question that asks students to identify the example that best applies a specific concept requires more critical thinking and analysis than a question that asks students to identify the correct term for a given definition (Schafersman, 2011). Ennis (2009) stated that multiple-choice questions are more labor intensive to create than equally effective open-ended critical thinking assessments, multiple-choice tests are easier to grade. To enhance students' processing skills, it is important to review test questions and explain correct answers by modeling the critical thinking. Some educational researchers have recommended that critical thinking should be made explicit to learners, ensuring clarity about what they are aiming to achieve (Lai, 2014; Yang, *et al*, 2013). This lends support for the addition of explicit critical thinking instruction to be

purposefully incorporated into the science course of this research study in order to ensure that students gain deeper understanding and clarity of the context that is taught.

2.1.7 Explicit and implicit critical thinking skills instruction.

In the integration of CTS into Science teaching, two pedagogical approaches are often considered, which include explicit and implicit instruction. Explicit instruction is defined as creating awareness of a rule through instruction. In contrast to this, implicit instruction means that learners speculate a rule for themselves without receiving any awareness of this rule via instruction (Ellis *et al.* 2009). The explicit instruction also referred to as "infusion approach" which means direct teaching of CTS principles, especially those related to the course content. Whereas, the implicit instruction, also referred to as "immersion approach", does not make CTS instruction distinct (Ennis, 2011). In other words, the explicit instruction aims to propel CTS competence by making the expected CTS and dispositions clear to students. However, in the implicit CTS instruction, although students might be well engaged in deep course content learning, but basic CTS concepts are not introduced, it is expected that their CTS can be developed as a natural consequence of the content learning.

Halpern, (2007) in his study stated that in order to effectively incorporate CTS in the rich context of specific courses, explicit instruction must be utilized, as learning how to think critically is not an automatic by-product of studying certain subjects (Beyer, 2008). The research work of Gelder (2005), shows resistance to the indirect approach, he stated that subject course instruction, even with implicit emphasis on critical thinking skills, will not adequately prepare students to become excellent critical thinkers. Hence, he suggests that CTS be practiced deliberately and taught explicitly as an indispensable part of the curriculum. The effectiveness of explicit CTS instruction has also gain empirical support.

Based on previous studies, Abrami *et al*. (2008) concluded that although the results were mixed, explicit teaching generally had larger effects on CTS development, whereas the implicit instruction was least effective. Bensley and Spero (2014) also conducted a study which revealed that in regular course instruction, direct teaching of specific CTS significantly improved high school student's CTS performance and metacognition. Teaching CTS explicitly is exceptionally necessary to students from non-western cultural background as they are found lack of experience and practice in CTS (Egege & Kutieleh, 2014).

Explicit instruction in biology classrooms requires that teachers must not only understand how CTS relates to ecology learning, but also be able to explain, model, and infuse the concept of CTS into their lesson designs and classroom activities. In teaching ecology, for example, teachers can explicitly teach the following key CTS related to ecology through explaining, modeling, as well as student practicing. These skills include analytical skills (analysis), identifying main claims and summarizing the main idea; inferential skills (inference and interpretation), making predictions, drawing logical conclusions, and interpreting result or findings; and evaluative skills (evaluation and explanation), such as evaluating the accuracy and credibility of the claims, evidence, and sources, evaluating the logic strength of arguments, distinguishing facts from opinions.

Specific procedures for explicit teaching of these skills can follow the guidelines suggested by Beyer (2008), which consist of (a) detailed explanations and modeling of critical thinking skill procedures and rules; (b) explicit instruction on how and when to apply a critical thinking skill; (c) systematic skill practice for autonomous use; and (d) supportive feedback and continuing coaching. Meanwhile, explicit instruction should simultaneously attend to CTS dispositions. With regard to biology, for example, the desired CTS dispositions may include such traits as being flexible in considering

alternative views and explanations other than those given by the teacher, being open-minded and not allowing personal expectations or biases to interfere with text understanding, and habitually questioning and challenging the teacher. In explicit instruction, teachers can explain these dispositions or model how an ideal critical thinker with these attributes may behave and think. It is essential that teachers explicitly communicate to students that these dispositions are highly valued and expected in learning biology.

2.1.8 Critical thinking instrument

In order to determine the effectiveness of project-based learning on the improvement of critical thinking skills, the teacher must first identify an appropriate assessment to measure critical thinking. However, identifying reliable measures of critical thinking improvement proved to be as challenging as defining the construct itself (Hatcher, 2011). Researchers have made several suggestions for designing assessments ideally suited to assess critical thinking skills. According to (Coyne *et al.* 2016) the assessments must be able to measure both the driving question and the educational goal. There are many methods of assessment to determine student growth and gains in regards to academic and 21st-century skills. The project-based learning model provides multiple avenues to calculate this data. Research literature identifies multiple-choice exams, open-ended essays, summative assessment and formative assessment, rubrics and mixed assessment approaches as the predominant instruments of critical thinking.

Ennis (2009), a leading theorist in the instruments of critical thinking and coauthor of the Ennis Weir Critical Thinking Essay Test explains that critical thinking instruments must begin with the assessment's intended purpose in mind in order to be effective. Possible outcomes of critical thinking instruments include (1) Determining levels of critical

thinking ability; (2) Providing student feedback about critical thinking strengths and weaknesses; (3) Motivating students to improve their critical thinking skills; (4) Providing teachers with data about the effectiveness of instructional practices targeted at improving critical thinking; (5) providing the necessary comparison data to conduct research (Ennis, 2009). In order for the instruments to be reliable, the teacher must first effectively define critical thinking and then determine the appropriateness of the assessment to their students (Ennis, 2009).

Hatcher's (2011) comparison study analyzes various instruments of critical thinking including popular measurements such as the Ennis-Weir Critical Thinking Essay Test (E-W), the California Critical Thinking Skills Test (CCTST), and the Cornell Level Z Critical Thinking Test (CLZ). The students in the sample each completed a pre-test and post-test. The study concluded that even though students showed greater gains on the essay test (E-W) than the multiple choice assessments (CCTST, CLZ), these gains could be due to the fact that the essay test more closely resembled what the course required students to master Hatcher (2011). Courses requiring students to write, which Tsui's (2012) case study demonstrates to be a crucial component of critical thinking development, show larger improvement gains on an essay-based assessment.

Hatcher (2011) reinforces Ennis' (2009) claim that regardless of the assessment of choice, teachers much first define critical thinking and what skills the construct entails and then choose a test that best assesses those skills. Students perform better on assessments when the assessment measures the skills the teacher defines as essential. Ku (2009) explains further that a more holistic instrument to measuring critical thinking has emerged. One such instrument is the Halpern Critical Thinking Assessment, an assessment that includes both a multiple-choice and written component. In their study of the development of critical thinking skills in high school students in low performing schools. One of the few

of its kinds as empirical studies of critical thinking in adolescents are rare, Marin and Halpern use the Halpern Critical Thinking Assessment as their instrument (Anderson & Krathwohl, 2011). The study conducted a two-phases demonstrates where students were exposed to both content-embedded and explicit instruction in critical thinking skills which show improvement as measured by the instrument. The results also prove "that helping students learn critical thinking skills can be done without a comprehensive restructuring of the high school curriculum" (Marin & Halpern, 2011,). Additionally, the Halpern Critical Thinking Assessment proves reliable not only in this study, but the instrument provides a holistic assessment of critical thinking by measuring student response beyond simply identifying the correct answer (Ku, 2009).

Table 2.1: Summary of Critical Thinking Instruments

Instruments	**Author**	**Measured**
Eninis, Weir Critical thinking Essay Test (EWCT)	Ennis, R. H. (1985)	Recognition, Augmentation, Inference and Reasoning.
California, Critical thinking Skills Test (CCTST)	Facione, P.A. Facione N. C. and Giancarlo, C (2007)	Reasoning sills, Analysis, Interpretation, Evaluation, Explanation, Inference, Deduction Induction and Numeracy.
Cornell Level Z Critical (CLZ)	Ennis, R. H. (2009).	Induction, Deduction, Credibility, Identification of Assumptions Semantics Definition, Prediction in planning experiment.
Halpern Critical thinking Assessment. (HCTA)	Halpern (2021)	Decision Making, Problem solving, Hypothesis testing Augment assumption, Judging likelihood and Uncertainty verbal reasoning.
Watson Glaser Critical Thinking Appraisal (W-GCTA)	Watson and Edwin (2010).	Inference, Recognition of Assumptions, Deductions, Interpretation, Evaluation of Arguments.

The results of the study build upon (Hatcher's 2011) claim that critical thinking assessments that measure the skills taught by the teacher produce the most significant gains in critical thinking skills. Assessments embedded within actual course content, particularly when the length of the study is shorter, increase the likelihood of this outcome and actually teach the skills that teachers believe their students need to learn (Fliegel & Holland, 2013). Therefore, in this research study, the researcher will be adapting the California Critical Thinking Skill Test (CCTST) because from the table above it is the these scales: Analysis, Interpretation, Evaluation and Inference, which serves as important variables to the study.

2.1.9 Project-based learning and critical thinking skills

PBLA is designed to facilitate students in getting to know the real world through increasing learning activities (Cervantes *et al.* 2015). Learning activities are carried out by involving students in managing learning, students learn by using prior knowledge (Jacques, 2017; Ilter, 2014). When students are engaged in PBLA approach, their critical thinking skills increase on a high level (Anazifa & Djukri, 2017; Desinta *et al.* 2017; Rachmatullah & Ha, 2019). PBLA increase students' critical thinking skills because during the learning process students are directly involved. Students have experience discovering facts through activities seeking information and combining various knowledge from various kinds of subjects (Li, 2018).

Florea and Hurjui (2015) found that learning that develops students' critical thinking skills must be developed in the learning process that accommodates high-level thinking skills, taking into account the quality of questions, the quality of thinking, and the quality of response. In the research of Asan and Haliloglu (2015); Anazifa and Djukri, (2017), they reported that PBLA improve the ability to work in groups, so as to improve team work

skills and also increase learning motivation as well as encourage students to help develop questions and find solutions. PBLA does not only equip the students with knowledge but also improve their problem-solving skill, critical and creative skill, lifelong learning, communication skill, team work, adaptation to changes, and self-evaluation (Khoiri *et al*. 2013). In PBLA, the real-world problems are used to motivate the students through the problems (Kaharuddin 2018). When solving the problems, there is information exchange among students so that the problems can be overcome and arrive at a solution.

According to Hartini *et al.* (2020), there is significant influence of critical thinking on students' learning outcomes when PBLA is implemented. Thus, this occurs because PBLA is based on student's activities. Some researchers have reported that students in taught using PBLA improved problem-solving and critical thinking skills. Another researcher found that PBLA has been a successful method of teaching 21st-century skills (Hartini *et al*. 2020). Furthermore, students also have shown more initiative by utilizing resources and revising works, also students' behaviors were uncharacteristic before they were immersed in the PBLA-instructed classes (Baron, 2018).

Implementation of PBLA could improve critical thinking skills, creativity, learning motivation and student learning outcomes as in the study of (Insyasiska *et al*. 2015; Sasson *et al.* 2018; Mutakinati *et al.* 2018). Similarly, with (Putra 2016; Asri *et al*. 2017; Ismuwardani *et al,* 2018) who have done research using project-based learning approach, from the result it shows that PBLA is capable of increasing independence, creativity, and critical thinking. Hence in this study the researcher seeks to find the outcome of using PBLA to improve critical thinking skills and students' achievement.

2.1.10 Ecology

Ecology is derived from the Greek word oikos meaning “household”, “home”, or “place to live” and logos meaning “the study of”. It is the study of the interactions of organisms with each other and their environment. Ecology is concerned with the study of interrelationships between organisms and their environments. The term ‘ecosystem’ was proposed by a British ecologist Tansley (1993). The ecosystem represents the basic functional unit of ecology which comprises of the biotic communities mutually related with their nonliving or abiotic environment. Thus, a biotic community and its abiotic environment together represent an ecosystem. Ecosystem, therefore, includes both the living organisms (biotic community) and the nonliving environment (abiotic environment) which is inseparably inter-related and interacts upon each other.

Odum and Barrett (1971), has defined the ecosystem as the basic fundamental unit of ecology which includes both the organisms and the nonliving environment, each influencing the properties of the other and each is necessary for the maintenance of life. Cardelu´s and Middendorf (2013) has given another definition of ecosystem according to which ecosystem is the sum total of living organisms, the environment and the processes of interaction between the various components of the system (Odum, & Barrett, 1971). The concept of ecosystem can be best illustrated by the fact that holozoic animals cannot synthesize their food and depend upon plants either directly or indirectly. Even plants which are capable of synthesizing their own food depend upon the abiotic environment from which they receive light, water, carbon dioxide and mineral salts, other inorganic and organic substances of absolute necessity for the synthesis of food. The organic substances and some of the inorganic compounds are accumulated in the soil by the dead and the decaying organisms and the excreta of living individuals.

In a complex and fast-changing world, ecological science is uniquely equipped to address intricate environmental questions, and it is nowadays expected to contribute substantially to understanding and addressing environmental problems in local, regional, and global instances.

Ecologists have been rising to this challenge by producing research that is readily applicable to environmental problems been established, or strongly supported, by ecologists, such as the Sustainable Biosphere Initiative (Lubchenco *et al*. 2011). Cardelu´s and Middendorf (2013) reported that, most ecologists nowadays would agree that ecological science is not being taught as much as it should in the wider decision-making spheres. This may be due in part to teaching pedagogy which beset the ability of various professionals to integrate relevant scientific knowledge in making decisions and developing policy regarding environmental issues. There has been increasing concern with enhancing 'ecological literacy' in society. The current literature emphasizes on a teaching method that will enhance scientific knowledge and ecological thinking in identifying cause effect relationships in socio environmental systems, in order to allow more enlightened decision-making. Therefore, its primary pedagogical goals are cognitive and critical thinking.

The aim of teaching ecology is meant to enable learners to make informed decisions or take action on environmental issues (Cid & Pouyat 2013). In view of the important of ecology secondary school performance in ecology has been below expectation. The WAEC result of 2015-2018 was reported that there is persistent decline in students' performance in ecology. The study of Salihu and Abubakar (2015) also revealed that students do poorly in ecology concepts due to the poor method of teaching ecology. However greater achievement in ecology concept can be obtained through activity-oriented pedagogy like PBLA, inquiry-based learning, problem-based learning. Hence

the need for methods that are activity based which will motivate students into learning using different methods of teaching in view of the preceding, PBLA approach is adopted for this study with the view it will enhance students meaningful learning of ecology.

2.1.11 Gender

Gender is a general term that is refers to as sexual categories that are male and female. Gender is an inherited gender influence by social and cultural factors that shape psychology and one's role so that it affects how individual think, behave and feel a phenomenon within themselves (Santrock 2011). Ramdiah and Corebima (2014) state that the difference on biological growth particularly in term of gender causes significance difference between critical thinking skills of students. Gender differences in biology critical thinking skills and achievement has remained a source of concern as scientists seek to address the under-representation of female at the highest levels of sciences, technology, engineering and mathematics, (Asante, 2010).

Based on research it has been revealed that the difference on gender influences the scores of students' critical thinking significantly (Aziz *et al.* 2013). Similarly, Rachmatullah and Ha, (2019) pointed out that there are differences in cognitive processes of male and female students in solving chemical problems. Consequently, the research result of Ryzal and Tanggal (2019) pointed out that the scores of female students critical thinking skills is higher than that of the male students. More so, Walsh and Hardy (2019) found that in a comparison of academic achievement and gender from Facione's California Critical Thinking Disposition Inventory, female scored higher than males in critical thinking disposition. Fortin, (2015) conducted a study on leaving boys behind, in their study, the results shows that female students are greater achievers than the male students in their academics.

Ajai and Imoko (2015) also conducted a study, in his study it was revealed that female students performed better than the male students. Although, the differences in the scores was not much. In another research it has been reported that female students have higher critical thinking Skills and problem-solving skills compared to the male students (Vural, 2013). This report was different from the research results conducted by (Gok, 2014) in the research, it was reported that there was no difference in understanding the concept between male and female student, still the difference was found on the problem solving that male are superior in problem solving ability than the female counterpart. Torrance (2013) argues that there was no gender difference in performance at tests, measured creative potential, but there were some significant differences between genders in self-perception, male perceive themselves as inventors than the females.

Holmes and Hwang (2016) carried out a study on PBLA on achievement in their result, it shows that the male students performed better than the female students in their test scores. In another study, conducted by Hans *et al.* (2015) it was reported that male students outperform their female counterpart in their achievement test scores. A study which was carried out by OECD examining problem solving and gender found that gender differences for adolescents were not statistically significant. A study conducted by Zetriuslita *et al.* (2016) on critical thinking ability shows that gender differences is significant at high level critical thinking skills ability, while at moderate or low levels those difference is not significant. Another study carried out by Bart *et al,* (2015) demonstrated that statistically significant differences exist between females and males. This study indicated the gender differences between students in year 11 were higher among students in year 8. This report was in agreement with Halpern's study, stating that critical thinking could be developed through gaining experience or transferring the knowledge to others (Bagheri & Ghanizadah, 2016).

The relationships between 'gender and achievement', 'gender and critical thinking' have not been precisely discovered. Although critical thinking is reported in contemporary literature broadly, the relation between gender and critical thinking is not explored deeply. In view of foregoing, findings on gender and students critical thinking skills and achievement are inconclusive. Therefore, gender is considered as a moderating variable in this study, with the view it could yield important data and contribute empirical findings on the effect of PBLA on critical thinking skills.

2.1.12 Gender and achievement

Generally, it has been reported statistically worldwide that in education, an obvious gender gap exist in academic achievement between males and females with males lagging behind females in terms of grades, subjects, O level graduation, tertiary level enrollment and completion (Parker *et al* 2018). In the research of Voyer and Voyer (2014), their study showed that females outperform males at different stages in the school system and have better grades as well as for higher institution. Hartley and Sutton (2013) reported that male counterparts especially with regard to achievement, motivation, ability and self-regulation. Majzub and Rais (2010) argue that male underachievement is a topic of critical importance in Malaysia and around the world. In their research, they found out that girls were outperforming boys in almost all subject domains. Their study also revealed that the situation worsens as student progressed through the different levels of education.

This trend persists after a background check on students such as their socioeconomic circumstances. This indication has attracted attention to the so-called gender gap in educational achievement not only in science subjects but also in non-science subjects (Wach *et al.* 2015). However, previous studies showed that there are rather inconsistencies in the results concerning gender difference in different subject domains

of school achievement. In the preset study, the researcher focused on achievement in biology because the students' performance in this subject is seen as an important aspect of school achievement. Previous study revealed that there is a large-scale biology achievement by girls in comparison to boys. In the study of Igbo and Oyibo (2015) it was revealed that female student out performs their male counterpart in biology test that was administer to the students. However, the picture of gender differences in biology achievement is not clear while in the study carried out by Githae (2015) his result showed that there was no difference in the scores of both male and female. On the contrary Nwaokolo *et al.* (2019) revealed in their study that male students score higher than their female counterparts in ecological concept.

2.2 Theoretical Framework

2.2.1 Piaget's theory of cognitive development

Piaget, was particularly concerned with the way thinking develops in children from birth until they become young adults. Jean Piaget was a Swiss psychologist who wants to understand the nature of this development; he carefully observed the behavior of his own three kids. He usually presents problems to them, observe their responses slightly after the situations. Piaget called this method of exploring development clinical interview. Piaget believed that humans also adapt to their physical and social environments in which they live. Jean Piaget`s theory centered on development and learning theories. The development focus on the leaner's capabilities and the learning focuses on the realization of such capabilities and the education within the theory is extrinsic while in the cognitive theory, the behavior reflects the emergence of various psychological structures, organized units or patterns of thinking that influence on how children interpret the information. The

cognitive developmental theories explain the change in reasoning level of a child acquiring new ways of understanding their world (Huitt & Hummel, 2003).

Piaget's theory of implication assumes that all children go through the same sequence of development, but they do so at different rates. Teachers must make a special effort to provide classroom activities for individuals and small groups, rather than for the total class group. Assessment should be based on individual progress, rather than on the normal standards of same age peers. Individuals construct their own knowledge during the course of the interaction with the environment. An important implication of Piaget's theory is adaptation of instruction to the learner's developmental level Piaget, (1983). According to Piaget, the process of adaptation begins from birth. Piaget described this adaptation in three terms namely, assimilation, accommodation and equilibrium.

1. **Assimilation:** He defines assimilation as the process by which new objects and events are grasped or incorporated within the scope of existing schemes or structures. According to Piaget (1983) Assimilation is the components of the adaptation when the information arises that can fit into the learner existing knowledge is added into the learners' cognitive structures. This information adds to extends the learners mind structures or cognitive structures. It actually occurs if the knowledge that learner is learning is not too dissimilar to learners existing knowledge; it can be assimilated or added to the existing cognitive structures.

2. **Accommodation**: According to Piaget the accommodation is the component of adaptation and is actually when the new information arises and contradicts or conflicts with the learners' cognitive structures. In accommodation, learner have to adjust and reshape his/her cognitive structures so that the new information can be fitted or accommodated in learner's mind. It actually occurs if the new

knowledge is very dissimilar to the existing knowledge and it cannot be linked with the existing knowledge. When disequilibrium occurs, it means the learners cognitive structures is modified or changed in order to accommodate the new knowledge.

3. **Equilibrium:** equilibrium is when the learner moves towards more complex or effective way of organizing and dealing with the world. Equilibrium according to Piaget is regarded as the engine that drives the development of a learner. It is actually the cognitive structures that accommodate the familiar information instead of the new knowledge, we say the learner equilibrates. In the equilibrium the assimilation and accommodation interact continuously and accommodation opens up possibility of assimilation and vice versa in an ever-expanding cycle.

The content of instruction needs to be consistent with the developmental level of the learner. The teacher's role is to facilitate learning by providing a variety of experiences. Teacher should obviously provide opportunities for learners to explore and experience, by doing so is encouraging learner's new understandings. Piaget emphasizes the Opportunities that allow learners of different cognitive levels to work together and encourage less mature students to advance to create understanding. Piaget, (1983) the further implication for instruction is the use of concrete hands-on experiences to help learners learn additional suggestions. Piag*et al*so emphasizes that teachers should allow opportunities to classify and group information to facilitate assimilating new information with previous knowledge as well as presenting problems that require logical understanding.

The important of Piaget's theory of cognitive development is the fixed progression from one stage to another. Piaget believed that all children progress through four stages and

they do so in the same order. Each stage has an age span with distinctive learning capabilities. This would be helpful in framing curriculum. And understanding of this development sequence is indispensable for teachers because these influences a great deal during infancy, childhood and adolescence. According to Bukatku, and Daehler, (1995) during each stage of cognitive development, there is unique level of analysis, internal organization and the understanding of the environmental information and events. Piaget`s theory shows clearly that the child`s understanding is particularly dependent on the stage that he/she has reached and teachers ought to take this into account as they teach learners at different levels of intellectual development. The 4 developmental stages are discussed below.

1. Sensori-Motor Stage (2 years): This is the first stage of growth development and it begins at birth and lasts till the child is about 2 years old. children have the basic structure of organizing and adapting to their environment and their behavior tend to be circular and also develop an elementary understanding of the things around because in this stage, children's thinking involves seeing, hearing, moving, touching, testing and so on. This stage marks a transitional stage for a person from a biological to a psychological being. In the first few weeks of life the baby's behavior consists simply of reflex responses, such as sucking, stepping and grasping. Later the reflex disappears and the baby chooses what and when to grasp. During this period the infants attain the concept of object permanence. This refers to the understanding that objects and events continue to exist even when they cannot directly be seen, heard or touched. Till this kind of understanding is achieved, an object that is out of sight remains out of mind and therefore, becomes non-existent. Another major accomplishment in the Sensori-Motor stage is learning to reverse actions. E.g. a detachable that has 10 parts given to a child, through constant practice the child will eventually learn to fix all parts of the.

2. **Preoperational Stage (2 - 7 Years):** in this stage, children have not yet mastered the ability to perform mental operations. The child on this stage is able to reason and give logical train of thoughts. In this stage the child uses the objects and symbols to represent something which exist in a concrete form for example: child play with a car as if it is a real car. At this stage the child is not yet able to conceptualize abstractly and needs concrete physical situations Children's thinking during this stage is governed by what is seen rather than by logical principles. In the Pre-Operational Stage children are characterized by:

(a) Semantic function: in this stage the child develops the ability to think using symbols and signs. Symbols represent something or someone else; for example, a doll may symbolize a baby, child or an adult.

(b) Egocentrism: In this stage is characterized by egocentrism. Children believe that their way of thinking is the only way to think.

(c) Decentring: A pre-operational child has difficulty in seeing more than one dimension or aspects of situation. It is called decentring.

(d) Animism: In this stage children tend to refer to inanimate objects as if they have life-like qualities and are capable of actions.

(e) Seriation: In this stage the child lack the ability of classification or grouping objects into categories.

(f) Conservation: It refers to the understanding that certain properties of an object remain the same despite a change in their appearance. -

3. Concrete Operational Stage (7 - 11 years): At this stage a child is concerned with the integration of stability of his cognitive systems. Child is capable of using logical processes of reasoning on the basis of concrete evidence Lazarus, (2010). Children who attain formal operations are said to reason in terms of theories and abstractions, as well as concrete realities. It is in this stage that problem solving and reasoning is powerful enough to last the rest of life. Child is capable of creating logical structures that explain his or her physical experiences and abstract problem solving is also possible at this stage. He learns to add, subtract, multiply and divide. He is in a position to classify concrete objects. In short, children develop the abilities of rational thinking but their thinking is tied to concrete objects.

4. **Formal Operational Stage (11 and above):** This stage is characterized by the emergence of logical thinking and reasoning. Thinking is not only abstract but also logical Lazarus (2010). The reasoning engaged in is not driven necessarily by the presence of the concrete objects but children can now generate the potential solutions to the problems in a systematic fashion. The social context is more important in this stage. The stage occurs during early adolescence and at this stage the child engage in more abstract thin thinking By this point, the child's cognitive structures are like those of an adult and include conceptual reasoning. This is the highest level of thinking stage and child is capable of going beyond the concrete evidence. The learner at this stage is able to concentrate their thoughts on things that have no existence. In this stage the child is now able to carry out variety of task that involves the ability to think about the hypothetical possibilities and to solve problems through logical deductions and in a systematic manner.

Hence the reason why the researcher has chosen to teach ecology using PBLA in the senior class because according to Piaget theory, which the student falls under the formal operational stage of development (11 years and above) students are not only able to

thinking abstractly but also can think logically. Therefore, the choice of using PBLA instructional strategy to enhance student critical thinking skills will be very effective for student at this stage of development.

2.2.2 Link between piaget's theory of cognitive development and current study

To reiterate, Piaget's theory of cognitive development emphasizes the nature of knowledge and how humans acquire, construct and use it. The current study underscores this by enhancing students' critical thinking skills and ecological achievement using PBLA in testing the practicality of the theory. In operationalizing this, the study deemed it appropriate focus on the formal operational stage (11 and above in age) of the developmental stages which the theory is premised. In this stage, students from age 11 and above were seen as perfect fit due to their level of mental alertness and maturity and based on the fact that this is average age of students in the Senior Secondary Schools in Nigeria (World Bank, 2019). At this stage of a child's development, there is emergence of logical thinking and reasoning (children are able to generate potential solutions to problems in a systemic and logical order). Even so, children develop a cognitive structure like that of adults for enhanced abstract and conceptual thinking. More so, to achieve the underlying objectives of the study, the selected samples have a robust assimilation, accommodation and equilibrium ideals that will fit the PBLA tasks the study presents in Biology.

Furthermore, the theory supported the engagement of students in the learning of abstract concept and critical thinking processes. The use of a teacher in this study is supported by this theory. Consequently, the theory provided the adequate support for the use of PBLA to enhance Critical thinking skills and achievement in ecology.

2.3 Empirical Studies

2.3.1 Project-based learning and critical thinking skills

Researchers have undertaken specific studies on PBLA and CTS (Purba *et al.* 2015; Rochmahwati, 2015; Desinta *et al*. 2017; Jusmaya & Efyanto, 2018; Astra *et al*. 2019; Alawi *et al*, 2019; Suastra & Ni, 2019). The individual studies categorized on PBLA and CTS are discussed in the succeeding paragraphs.

Purba *et al.* (2015), a study focused on the effect of project-based learning and conventional learning strategies on critical thinking ability using all graders 11 in academic year 2015. In their study, a quasi-experiment was adopted as a pretest and posttest control design group. Cluster sampling technique was used to select two classes in which students in class 11C was taught using PBLA strategy, and those students in 11D were taught using conventional learning strategy. The Research instruments was critical thinking ability (Cognitive test C4-C6). The assumptions showed that the data were normally distributed and homogenous. The ANCOVA (Analysis of Covariance) and Tukey's test were used for hypothesis testing by using SPSS version 19 statistical software. The result showed that students who were taught by project-based learning strategy (77.88 ± 7.35) had significantly different critical thinking ability compared with those who were taught with conventional learning strategy (68.05 ± 10.38). Based on the result of the research it can be concluded that students taught using project-based learning had higher critical thinking ability than those students taught using conventional learning strategies.

The similarities between the current study and the previous study is that both measured students critical thinking skill, however, the current study also measured academic

achievement of student in Ecology as against the previous study which measured only critical thinking skills of students.

Furthermore, Rochmahwati, (2015) also carried out research on fostering student's critical thinking through Project- Based Learning. In his study, descriptive qualitative research method was used. The samples were the lecturer of TEFL 1 course and 25 students in a class of the fourth semester of STAIN Ponorogo who took TEFL 1 course. The instruments used are in the form of observation sheet and interview guideline. The data analysis applied in this research used data reduction, data display, and conclusion drawing. The findings showed that the implementation Project-Based learning that fosters the students' critical thinking in TEFL class are through the following steps: (1) Discussing the materials about English Language Teaching Method, (2) working with the group to construct scenario of teaching practice, (3) practicing the scenario, (4) recording the teaching practice into video, and (5) evaluating the video product. Moreover, the result of interview indicates that the students showed significantly positive attitude toward the implementation of Project-Based Learning. Finally, English teachers are recommended to implement Project-Based Learning in EFL class since it facilitates the students to build their critical thinking.

The difference between the existing study and the current study is that the existing study adopted a descriptive qualitative research method. In contrast, the current study adopted a mixed method explanatory sequential design which deals with both quantitative and qualitative method of data collection.

As opined by Desinta *et al.* (2017), they carried out a study that focused on the effects of Project-based learning to students' Critical Thinking skill, to ascertain the effects of self-regulated learning to students Critical Thinking skill, and to ascertain the interaction of

Project-based learning and self-regulated learning toward Critical Thinking skill. The study employed a quasi-experimental design posttest pretest method. The total population of this study was the entire students grade X in Senior High School Negeri 1 Balige, North Sumatera academic year 2017. The target sample was selected using cluster random sampling technique, namely X Science-1 grade as experimental class using PBLA model and X Science-3 grade as control class using conventional learning model. In their study, quasi experiment was adopted with two group pretest posttest design. The instruments used for data collection in their research were valid essay test of critical thinking skill and questionnaire of self-regulated learning. The data obtained were analyzed by using prerequisite and hypothesis test. The normality test was analyzed by Kolmogorov-Smirnov Test. The homogeneity test was analyzed by Levene's Test of equality error variance. Hypothesis test were analyzed by using 2x2 factorial design for technical analysis of two-way variance (ANOVA) with the level of significance 0.05. Based on the result of study, those students taught by PBLA had high Critical Thinking skills than those taught using conventional learning. Students with high Critical Thinking skill have high self-regulated learning better than students' with low Critical Thinking skill. In conclusion, Project-based learning and self-regulated learning has interaction to students Critical Thinking skill.

The similarities between the current study and the previous study is that both measured students critical thinking skill, however, the current study also measured academic achievement of student in Ecology as against the previous study which measured only critical thinking skills of students.

More so, Mustika *et al.* (2017) carried out a study on (PBLA) model used to teach students to think critically. The focus of the study was to ascertain the influence of the PBLA learning model on students' critical thinking skills. In their study, quasi-experimental pre-

test post-test research design using non-equivalent control group design. Simple random sampling technique was used in the study. The instruments used for data collection was an essay test. The data collected was analyzed using t-test. Based on the result of the data analysis, the average score of student critical thinking skills in the experimental group taught using PBLA is 32.3, while the average score of students critical thinking skills in the control group taught using traditional learning method is 14.2. Thus, PBLA was more effective than the lecture method.

The difference between the current study and the previous study is that both studies were carried out in different subject scope. The current study subject scope was Biology as against the previous study which the subject scope was Geography.

In congruence Jusmaya and Efyanto (2018) also conducted research focused on fostering students' critical thinking through PBLA. The research was carried out to find out the effect of PBLA towards Critical Thinking of University students in Batam. In their study, they adopted a quasi-experimental research method. There are three pre-tests and post-tests. The pre-test was used to see students' Critical Thinking before having treatment and post-test are used to see the differences on students critical thinking after giving treatments. In their study, random sampling technique was used to select students from English Department of Putera Batam University who took Speaking class. The instrument used in obtaining data was Critical Thinking test. The data was analyzed using T-test. The result of the study showed that that PBLA has a significant effect on students' Critical Thinking skills this conclusion was based on the analysis that has been done where t cal > t tab. t cal = 3, 83 and t tab 2.36 with standard significant 0,05. Thus, it can be concluded that Critical thinking skills can be increased by using Project-based Learning method

The difference between the existing study and the current study is that existing study measures only critical thinking skills using quasi-experimental method. In contrast, the current study focuses on student's critical thinking skills and achievement.

Additionally, in a study carried out by Astra *et al.* (2019), in a bid to determine the effect of project-based learning model assisted by student worksheets on students' critical thinking skills in learning physics. The samples were selected using purposive sampling technique. The research was conducted using sample class 10 IPA I which was the experimental group and class 10 IPA II which was the control group in the academic year 2018/2019. In their study, quasi-experimental method with unequal pre-test-post-test control group design. The experimental group was taught using PBLA model assisted by student worksheets and the control group was taught by using traditional learning model. The data were collected by using tests of critical thinking skills gotten from the pre-test and post-test. The data obtained was analyzed using T-test and the results showed that students who were taught using PBLA model assisted by student worksheets had an average score of critical thinking skills of 74.57 higher than students who were taught using traditional learning model with an average score of critical thinking skills of 61.29. Based on the results of their study, it was concluded that the implementation of project-based learning model assisted by student worksheets has a positive influence on students' critical thinking skills in learning physics on work and energy.

The difference between the current study and the previous study is that both studies were carried out in different subject scope. The current study subject scope was Biology as against the previous study which the subject scope was physics.

On the contrary, Alawi *et al.* (2019) also conducted a study on Project-based learning (PBLA) to foster student's critical thinking skills which he said to be one of the key

elements of STEM education. The aim of their study was to identify the effect of PBLA method on the critical thinking skills of Form Four Students on Dynamic Ecosystem topic "Vector! Oh! Vector!" at Zainab, Kota Bharu, Kelantan. In their study Quasi-experimental research method used adopted to conduct the study. The instrument used was achievement test that was administered in the form of a pre-test post-test. The sample consisted of 60 students that divided into treatment groups which consist of students taught using the PBLA method and the control group which consist of students taught using the conventional learning method for four weeks. In the result of the study, it shows that there is a significant effect on the improvement of students' critical thinking skills using PBLA which were the construct that include comparing and contrasting, grouping and classifying, analyzing, deducting and evaluating in treatment groups compared to control groups.

The similarities between the current study and the previous study is that both measured students critical thinking skill in Ecology, however, the current study also measured academic achievement of student in Ecology as against the previous study which measured only critical thinking skills of students.

Consequentially, Suastra and Ni (2019) conducted a study aimed to analyze the effect of PBLA model on critical thinking, scientific attitude, and self-efficacy in students. This study used a quasi-experimental research method of post-test only control group design. 60 ninth grade students of public high schools in Singaraja in the academic year 2018 were used. In their research the samples were selected using simple random sampling technique in which 30 students were assigned to the experiment class while the other 30 were assigned to the control class. The instruments used were critical thinking test, scientific attitude questionnaire, and self-efficacy questionnaire. The data were analyzed using descriptive statistics to test the hypothesis, MANOVA (Multivariate analysis of

Variance) with the 5% significance level was used. The result showed that there is a significant difference in critical thinking, of the students who were taught with PBLA from those who were taught with conventional learning. The group of students who were taught with PBLA had a high mean score than that of those who were taught with conventional learning. In other words, PBLA is effective in enhancing critical thinking, scientific attitude, and self-efficacy of the students in science teaching.

The difference between the existing study and the current study is that the existing study measures critical thinking, scientific attitude, and self-efficacy in students using quasi-experimental research design and questionnaire. In contrast, the current study measures critical thinking and academic achievement using a mixed method explanatory sequential design.

Table 2.2: Summary Table on PBLA and CTS

Authors	**Research**	**Methodology**	**Instructional content**	**Result**
Purba *et al* (2015)	Effect of project-based learning and cooperative type group investigation learning strategies on higher order thinking ability in biology course	Quasi-experimental research design	Biology	The result showed that student taught using PBLA had higher critical thinking ability than those taught using conventional learning strategies
Rochmahwati (2015)	Fostering Students' Critical Thinking by Project-Based Learning	Descriptive quantitative research design	English	The findings showed that the implementation Project-Based learning fosters the students' critical thinking in TEFL class

Alawi *et al* (2019	The effect of project-based learning (PBLA) on critical thinking skills form four Students on dynamic ecosystem topic "vector! oh! vector!"	Quasi-experimental research design	Biology (dynamic ecosystem)	The result of the study, shows that there is a significant effect on the improvement of students' critical thinking skills using PBLA.
Astra *et al* (2019)	Effect of project-based learning model assisted by student worksheet on critical Thinking abilities of high school students.	Quasi-experimental research design	Physics	The results showed that students who were taught using PBLA model assisted by student worksheets had an average score of critical thinking skills of 74.57 higher than students who were taught using traditional learning model with an average score of critical thinking skills of 61.29.
Mustika *et al* (2017	Effect of PBL Learning Model on Critical Thinking Skills Students Learning Course Design of Geography	Quasi-experimental research design	Geography	Desinta *et al* (2017)
Jusmaya and Efyanto (2018)	Empowering Student's Critical Thinking By Applying Project-based Learning	Quasi-experimental research design	English	The result of the study showed that PBLA has a significant effect on students' Critical Thinking skills this conclusion was based on the analysis that has been done where t cal > t tab. t cal =

				3,83 and t tab 2.36 with standard significant 0,05.
Suastra and Ni (2019)	Developing Critical Thinking, Scientific Attitude, and Self-efficacy in Students through Project-based Learning and Authentic Assessment in Science Teaching at Junior High School	Quasi-experimental research design	Physics	The result showed that there is a significant difference in critical thinking, of the students who were taught with PBLA from those who were taught with conventional learning. The group of students who were taught with PBLA had a high mean score than that of those who were taught with conventional learning.

2.3.2 Project-based learning and achievement in biology

Researchers have undertaken specific studies on PBLA and achievement (Bas 2011; Purba *et al.* 2015; Kizkapan & Bektas, 2017; Jusmaya & Efyanto, 2018; Oludipe & Olupide 2019; Retnaningsih & Nugrahaningsih, 2019; Anteplioglu, 2019). The individual studies categorized on PBLA and achievements are discussed in the succeeding paragraphs.

In addition, Bas (2011) carried out a study focused to investigate the effects of project-based learning on student's academic achievement and attitudes towards Biology lesson of 9th grade students. The research was carried out using grade 9 students in 2011 academic year in Nigde, Turkey. The sample size was a total of 60 students who were selected using simple random sampling technique. The researchers adopted a Quasi

experimental the pre-test and post-test control group research design for their study. The data was obtained using an academic achievement test and were analyzed SPSS version 17.0. The arithmetic means and standard deviations were calculated for each group. In order to test the significance between the groups, the independent samples t-test was used. The significance level was taken as .05 in the research. Based on the result of the study, it showed that there is a significant difference between the scores of the experiment group and the control group. On the other hand, it was also found out that PBLA was very effective in yielding positive result of the student's academic achievement levels. In conclusion, the result showed that the students who learned by PBLA was more successful and had higher academic achievement towards the lesson than the students who learned by the instruction based on lecture methods.

The similarities between the current study and the previous study both measured students' achievement in Biology. However, the current study also measured academic achievement of student critical thinking skills in Biology as against the previous study which measured only academic achievement of students.

As opined by Purba *et al.* (2015), a study focused on the effect of project-based learning and conventional learning strategies on academic achievement using all graders 11 in academic year 2015. In their study, a quasi-experiment was adopted as a pretest and post-test control design group. Cluster sampling technique was used to select two classes in which students in class 11C was taught using PBLA strategy, and those students in 11D were taught using conventional learning strategy. The Research instruments was critical thinking ability (Cognitive test C4-C6). The assumptions showed that the data were normally distributed and homogenous. The ANCOVA (Analysis of Covariance) and Tukey's test were used for hypothesis testing by using SPSS version 19 statistical software. The result showed that students who were taught by project-based learning

strategy (77.88 ± 7.35) had significantly higher level of academic achievement compared with those who were taught with conventional learning strategy (68.05 ± 10.38). Based on the result of the research it can be concluded that student's taught using project-based learning perform better than those students taught using conventional learning strategies.

The difference between the existing study and the current study is that existing study measures only academic achievement using quasi-experimental method in Turkey. In contrast, the current study focuses on students critical thinking skills and achievement in Minna Niger state Nigeria.

According to Kizkapan and Bektas (2017) they conducted a study focused on determining whether there is a significant effect of project-based learning model on 7th grade students' academic achievement in biology. In their study, they used quantitative research methods, quasi-experimental design pretest-posttest control group was used. Convenience sampling technique was adopted for the study and 38 students participated in this study. The instrument used for data collection for the study was lesson plans, structure and properties of matter achievement test, and observation checklist. The data obtained was analyzed using independent samples t-test. Based on the findings of the results, there is no significant difference between the scores of the group taught using PBLA (experimental group) and those taught using lecture method (control group) which is obtained from their "Achievement test" post-test performance.

The difference between the existing study and the current study is that existing study measures 7th grades students' academic achievement using quasi-experimental method. In contrast, the current study focuses on students critical thinking skills and achievement using a mixed explanatory sequential design.

Consequentially, Jusmaya and Efyanto (2018) also conducted research focused on fostering students' critical thinking through PBLA. The research was carried out to find out the effect of PBLA towards Critical Thinking of University students in Batam. In their study, they adopted a quasi-experimental research method. There are three pre-tests and post-tests. The pre-test was used to see students' Critical Thinking before having treatment and post-test are used to see the differences on students critical thinking after giving treatments. In their study, random sampling technique was used to select students from English Department of Putera Batam University who took Speaking class. The instrument used in obtaining data was Critical Thinking test. The data was analyzed using T-test. The result of the study showed that that PBLA has a significant effect on students' Critical Thinking skills this conclusion was based on the analysis that has been done where t cal > t tab. t cal = 3,83 and t tab 2.36 with standard significant 0,05. Thus, it can be concluded that Critical thinking skills can be increased by using Project-based Learning method

The similarities between the current study and the previous study both measured students critical thinking skill, however, the current study was carried out in secondary school in Minna Niger State as against the previous study which was carried out in the University in Indonesia.

More so, Retnaningsih and Nugrahaningsih (2019) conducted a study focused on ascertaining the effectiveness of PBLA and assessment of learning outcome. The purpose of this study was to analyze the completeness of attitude, science process skills, improvement of learning achievement, and differences in learning achievement of students in the material of the motion system with PBLA models using portfolio assessment. In their study a quasi-experimental pre-test post-test control group design was used. The instrument used for the study achievement test. The data were analyzed

with the N gain test. Anova 1 way is used to see the difference between the two learning achievement scores of Experiment Groups 1, and 2 and Control group. Independent t-test is used to see Learning Achievement Levels for Experiments Groups 1 and 2. The results of the findings showed that Learning achievement in the motion system material with PBLA model using portfolio assessment increases than those in the control group.

The difference between the existing study and the current study is that the existing study uses the instructional approach to measures completeness of attitude, science process skills, and improvement of learning achievement, In contrast, the current study measures critical thinking and academic achievement using a mixed method explanatory sequential design.

Furthermore, Anteplioglu, (2019) conducted a study to examine the effect of PBLA for 7th grade science with a topic "Cell and Divisions," in terms of academic achievement, compared to traditional science instruction. The research method utilized was a pre and post-test control group quasi-experimental design. Simple random sampling technique was used to assign students to experimental group using PBLA and control group using traditional instruction. The instrument used for data collection was a "Cell and Divisions Achievement Test" which was administered prior to, at the end of, and one month after the implementation of PBLA. The data obtained were analyzed using independent t-test. The result of the findings showed that the score of students taught using PBLA performed at a significantly higher level than the control group. In Conclusions the intervention of PBLA is an effective means in attaining higher academic achievement. The difference between the existing study and the current study is that existing study ascertain students' academic achievement using quasi-experimental research design. However, the current study aimed to ascertain the level of students thinking skills and academic achievement using mixed method explanatory sequential design.

Oludipe and Olupide (2019) conducted a study aimed to examine the effect of gender and science anxiety on students' academic achievement in basic science at the Junior Secondary School level. The study was a quasi-experimental study. The population for this study comprised the Junior Secondary III (JSIII) students in Ogun State Junior Secondary Schools. A total sample of 120 students was drawn from three coeducational Junior Secondary Schools in three Local Government Areas of Ogun state. Basic Science Achievement Test and Science Anxiety Scale were the instruments used to collect data. Descriptive statistics, and Univariate Analysis of Variance (ANOVA), were used to analyze the data collected. The result of the analysis showed that there was a significant effect of on students' academic achievement taught using PBLA compared to those taught using conventional methods in basic science.

The difference between the existing study and the current study is that existing study ascertain junior students' academic achievement in Basic Science using quasi-experimental research design in Ogun State. However, the current study aimed to ascertain the level of senior students critical thinking skills and academic achievement in Biology using mixed method explanatory sequential design in Minna Niger State.

Table 2.3: Summary Table on PBLA and Achievement

Authors	Research	Methodology	Instructional content	Result
Bas (2011)	Investigating The Effects Of Project-Based Learning On Students' Academic Achievement And Attitudes Towards English Lesson	Quasi experimental research design	Biology	The result of the study showed that, PBLA was very effective in yielding positive development of the student's academic achievement levels
Purba *et al* (2015)	Effect of project-based learning and cooperative type group investigation learning strategies on higher order thinking ability in biology course	Quasi-experimental research design	Biology	The result showed that student taught using PBLA perform better than those taught using conventional learning strategies.
Jusmaya and Efyanto (2018)	Empowering Student's Critical Thinking by Applying Project-based Learning	Quasi-experimental research design	Biology	The result of the study showed that PBLA has a significant effect on student's academic achievement.
Kizkapan and Bektas (2017)	The Effect of Project-based Learning on Seventh Grade Students' Academic Achievement	Quasi experimental design	Biology	The results shows that there is no significant difference between the scores of the group taught using PBLA (experimental group) and those taught using lecture method (control group) which is obtained from their "Achievement test" post-test performance.

Retnaningsih and Nugrahaningsih (2019)	The Effectiveness of Project-Based Learning Model and Assessment of Learning Outcomes Against Portfolio	Quasi experimental design	Biology	The results of the findings showed that Learning achievement of students taught motion system with PBLA model perform better than those taught using lecture method..
Anteplioglu, (2019)	Effect Of Project-based Instruction On Science Achievement: An Experimental Study With 7th Grade Students	Quasi experimental design	Biology(cell division)	The result of the findings showed that the score of students taught using PBLA performed at a significantly higher level than the control group.

2.3.3 Gender and Critical thinking skills

Researchers have undertaken specific studies on gender and CTS and there were mixed findings (Shubina & Kulaki, 2019; Bagheri & Ghanizadeh 2016; Leach 2011; Harish, 2013; Fuad, 2017).

Leach (2011) conducted a study to determine if there were differences in the 5 dimensions of critical thinking skills using the California critical thinking skill test. The data collected from the CCTST include critical thinking skill dimension on analysis, deduction, evaluation, induction and inference. The study employed both a survey research design. The population of the study was based upon 1,455 graduating seniors for the 2010 academic year on the (CCTST). This study used descriptive and inferential statistics to analyze data obtained from CCTST and evaluate the five research questions. Null hypotheses were tested using a series of two-way analysis of variance (ANOVA). The

data were analyzed using SPSS statistical package. Findings from this study indicate that gender significantly influence the means on the dimensions of the CCTST. The result of the findings revealed that male students are critical thinkers than their female counterparts. The similarities between the existing study and the current study is that both study adopted the California critical thinking skill test to collect data on the levels of students critical thinking skills. However, the current study measure four sub-skills of student's level of critical thinking skill as against five sub-skills measured on student critical thinking skill level.

Also, Harish (2013) carried out a study aimed to examine empirically the effect of Gender, Intelligence and study habits on the critical thinking skills of secondary school students. A sample of 140 students was selected randomly from ninth standard students of Bangalore city. 2 x 2 x 2 factorial design was employed with two levels of gender: male and female, two levels of intelligence: high and low and two levels of study habits high and low. The analysis was carried out by employing three-way analysis of variance (ANOVA). The result of the analysis showed that gender has a significant at 0.01 level of confidence (F= 7.33 and *df* = 1 and 140). It means that gender has significant main effect on critical thinking skills. It indicates that the mean scores of males and females differed significantly. The mean score of males was 21.8 and female was 16.46. Obviously, the mean score of males is higher than the females. It means that males were better in critical thinking skills than their female counterparts. The difference between the existing study and the current study is that the existing study focuses on establishing the effect of gender, intelligence and study habit on students critical thinking skills in contrast, the current study focuses on establishing the effect of project-based learning on student critical thinking skills.

In addition, Bagheri and Ghanizadeh (2016) conducted a study to authenticate the significant role of higher-order thinking skills and meta-cognitive abilities, this study intended to investigate the association between the two subcomponents of critical thinking, inference-making and deduction, and one subcomponent of self-regulation, self-monitoring, as well as the role of gender in each of these constructs. In their study, survey research method was used; convenience sampling technique was used to select 120 EFL university students. They were asked to complete the Watson-Glaser's Critical Thinking Appraisal and the Self-Regulation Trait Questionnaire which served as the instrument for the study. They were also asked to indicate their gender on their questionnaires. The result of the study revealed that gender did not play a part in students' inference-making, deduction, and self-monitoring. The similarities between the previous study and the current study is that the previous study investigated the sub-component of critical thinking skills. However, the previous study uses Watson-Glaser's Critical Thinking Appraisal whereas the current study uses California Critical Thinking Skill Test.

Additionally, Fuad *et al*., (2017) also carried out a study that focused on (1) to find out the differences in critical thinking skills among students who were given three different learning models: differentiated science inquiry combined with mind map, differentiated science inquiry model, and conventional model, (2) to find out the differences of critical thinking skills among male and female students. In his study, is quasi-experimental research with pretest-posttest nonequivalent control group design was adopted. The sample population in his study was the 7^{th} grade students of junior high schools in Kediri, Indonesia. Random sampling was used to select 96 students who were assigned in three classes at different schools. The instrument used to obtain data was a scoring rubric of critical thinking skills which is gained from test scores and then analyzed using descriptive and inferential statistics through ANCOVA. The results of the research

revealed that there are differences in critical thinking skills between male and female students. Based on this research, it reveals that female students tend to do better in critical thinking skills compared to male students. The similarities between both study is that both aimed to find out the difference in the critical thinking skills among male and female students. However, the existing study was carried out in Kediri, Indonesia in contrast with the current study that was carried out in Minna, Nigeria.

For instance; Shubina and Kulaki, (2019) carried out a study aim to discover the relationship between critical thinking and creativity and empirically measure the level of their development among youngsters for knowledge generation and dissemination in education. In their study, they adopted a survey research method in order to empirically investigate the relationships between the variables. The data was collected using two tests in total, where the first test was measuring creative potential and the second test measuring critical thinking skills. To measure the level of creativity, the Kincher's creative potential scale was used. Critical thinking skills were measured using the structured questionnaire. Watson-Glaser Critical Thinking Appraisal tool. The data obtained was analyzed using statistical analysis SPSS software. The total sample was 220 participants: 86 female, 134 male. The findings of their study showed that existing relationships between all studied constructs are complex and influenced by other variables such as personality, social environment, educational system, technology usage and knowledge generation, teacher's philosophy etc. It was discovered that gender has a significant impact on critical thinking skills. The differences between the existing study and the current study is that the existing study aimed to discover the relationship between Critical thinking skills and creativity using a survey research method to collect data However, the current study uses a mixed explanatory sequential research design to collect.

Consequentially, Ryzal *et al.* (2019) carried out a study aimed to determine the students' critical and creative thinking skills in the Islamic senior high schools of Surakarta City so that teachers can pay attention to the strength and weakness of each student based on gender differences. This study used descriptive qualitative analysis. The sample of the study were selected using purposive sampling which amounted to 180 students consisting of 80 male and 100 female students. The instrument used for data collection of critical thinking was a 6 essay-question instrument of the chemical material of electrolyte and non-electrolyte solutions that measures the aspects based on Facione theory, namely: analysis, inference, explanation, interpretation, evaluation, and self-regulation. Then, to measure creative-thinking skills, a 4 essay-question test instrument of the chemical material that includes 4 aspects according to Torrance, fluency, flexibility, original and elaboration, was used. The data were analyzed using descriptive statistic, analysis of covariance (ANCOVA). The results showed that the creative-thinking skills of mal students are better than those of female students and the critical-thinking skills of female students are better than those of male students. The differences between the existing study and the current study is that the existing study focused on chemistry as a subject scope, However, the current study focuses on a biology as the subject matter. Table 2.4: Summary of gender and critical thinking skills.

2.4 Summary table on gender and critical thinking skills

Authors	Research	Methodology	Instructional content	Result
Leach (2011)	Critical Thinking Skills as Related to University Students Gender and Academic Discipline.	Survey research design	English	Findings from the study indicated that gender significantly influence the means on the dimensions of the CCTST
Harish (2013)	Critical Thinking Skills among Ninth Standard Students in Relation to Gender, Intelligence and Study habits	2*2*2 Factorial research design	Mathematics	The result of the analysis showed that gender has a significant effect on critical thinking skills. It indicates that the mean scores of males is higher than the females. It means that males were better in critical thinking skills than their female counterparts.
Bagheri and Ghanizadeh (2016)	Critical Thinking and Gender Differences in Academic Self-regulation in Higher Education	Survey research design	English literature	The result of the study revealed that gender did not play a part in students' inference-making, deduction, and self-monitoring

Fuad, *et al.*, (2017)	Improving Junior High Schools' Critical Thinking Skills Based on Test Three Different Models of Learning	Quasi experimental research design	Biology	The results of the research revealed that there are differences in critical thinking skills between male and female students. Based on this research, it reveals that female students tend to do better in critical thinking skills compared to male students.
Shubina and Kulaki, (2019)	Critical Thinking, Creativity and Gender Differences for Knowledge Generation in Education	Survey research design	English	The findings of their study showed that there was a strong negative correlation between gender and critical thinking it was concluded that females had higher CTS than the Males.
Ryzal *et al* (2019)	Analysis of Student Critical and Creative Thinking (CCT) Skills on Chemistry: A Study of Gender Differences	Survey research design	Chemistry	The results showed that the critical-thinking skills of female students are better than those of male students.

2.3.4 Gender and achievement in biology

Igbo and Oyibo (2015) carried out a study aimed to investigate the influence of gender stereotype as a predictor of secondary school students' self-concept and academic achievement. In their study ex post facto experimental design was adopted. The sample of the research was drawn from eight government senior secondary schools in Udi education zone. 9 schools were randomly selected from the 227 schools. A total sample of 342 senior secondary school II students (SSS II) made up the sample of the study. The instrument used for data collection was 20 item students stereotype self-concept questionnaire (SSSCQ) which was adapted from Marsh's Self Descriptive Questionnaire II (SDQII), and a 10-item students' mathematics achievement test (SMAT). The data collected was analyzed using mean and standard deviation which was used in answering the research questions while a *t*-test was used in testing the four hypotheses. The findings of the study revealed that gender has a significant influence on students' academic achievement in favor of the male students. The similarities between the existing study and the current study is that both study aims to establish the effect of gender on academic achievement. However, the current study also sought to ascertain the effect of gender on students in contrast to the existing study where critical thinking skill is not a variable.

Also, Nwaokolo *et al.* (2019) also carried out a study aim was to determine the comparative effects of individualized and cooperative video-based instructional strategies on secondary school students' achievement in Biology in Makurdi Metropolis, Benue State, Nigeria. In their study a quasi-experimental design of non-randomized pretest posttest control group was adopted. The entire population of the study consists of 1,907 while the target sample consists of 84 SS1 students which was drawn from two secondary schools using multistage sampling technique. In each school intact classes were randomly assigned to individualized video-based instructional strategy and cooperative video-based

instructional strategy. The instrument used for data collection was Biology Achievement Test (BAT). The Data collected was analyzed using Analysis of Covariance (ANCOVA) to test the hypotheses at 0.05 level of significance. The findings of the study reveal that there is statistically significant difference between the mean scores of male and female students when taught ecological concepts using individualized and cooperative video-based instructional strategies. The similarities between the existing study and the current study is that both study aims to establish the effect of gender on academic achievement. However, the existing study was carried out in Markurdi Benue State in contrast with the current study that was carried out in Minna Niger State.

On the contrary, Githae (2015) also carried out a study to investigate the effects of Collaborative Concept Mapping Teaching Approach on secondary school biology student's achievement in Nakuru North Sub- country, Kenya. The study adopted a Non-Equivalent Quasi-experimental research design, The sample consist of 202 SS II biology students which were selected randomly and purposive sampling technique was used to select four schools. A Biology Achievement Test (BAT) was used as instrument for data collection for both the pre-test and post-test. One-way ANOVA, t-test and ANCOVA were used to analyze the data generated with the aid of the Statistical Package for Social Sciences (SPSS). The results of the analysis indicate that there was a statistically significant difference in achievement between the experimental and control groups in favor of experimental groups. The findings show that Students' gender had no significant effect on achievement when they are taught through CCMTA. The difference between the previous study and the current study is the previous study was carried out in Nakuru North Kenya and the current study was carried out in Minna Nigeria. However, both studies aimed to establish the effect of gender on academic achievement.

In addition, Filgona *et al.* (2016) also carried out a study to investigate the Effect of Hands-On Learning Strategy on Senior Secondary School Students' Achievement in Topographical Map Studies in Mayo Belwa Local Government Area, Nigeria. The study adopted a quasi-experimental non-equivalent pre-test, post-test control group design comprising two groups made up of one experimental group and a control group. 205 students were randomly selected from SS III Geography students for the study and were assigned to experimental and control groups. The instrument used for data collection in this study was Topographical Map Achievement Test (TMAT). Independent samples t-test statistic and using Analysis of Covariance (ANCOVA) were used to analyze data. The findings of the study revealed that there was no significant effect of gender on the achievement of students taught topographical maps using hands-on learning strategy. The similarities between the existing study and the current study is that both study aims to establish the effect of gender on academic achievement. However, the existing study focuses on Geography as it subject scope in contrast with the current study that focuses on Biology as it subject scope.

Consequentially, Sheyin and Omolara (2018) also carried out a study to investigate the effects of Computer-Based pedagogy on the achievement of pre-service teachers in an ecology. Experimental research design was used in the study. The population of the study of 233 college of education biology students which were randomly selected. The instrument used for data collection was Achievement Test in Ecology (ATE). The data collected were analyzed using Analysis of Covariance (ANCOVA) to test the formulated hypotheses. The result showed that there was no significant effect of gender on students' academic achievement in ecology. The difference between the previous study and the existing study is that the existing study focuses on effect of gender on academic achievement on preservice teachers, whereas the current study focuses on the effect of

gender on secondary school students' academic achievement. However, both study uses the same content scope which is Ecology.

More so, Olupide, (2018) also carried out a study to determine the gender effects of cooperative learning on academic achievement of students in basic science in Ogun State, Nigeria. In their study, quasi experimental design was adopted and a total sample of 607 students from 6 junior secondary school were selected using random sampling technique. Data was obtained using basic science achievement test (BSAT) The data generated were analyzed using both descriptive and inferential statistics. Descriptive statistics used were means, standard deviation, while inferential statistics used was analysis of covariance (ANCOVA), using pretest scores as covariates Two research questions and hypotheses were formulated and tested at 0.05 level of significance. The result showed that there was no significant difference between the academic achievement of the male and female students exposed to the cooperative learning strategy. The difference between the existing study and the current study is that the existing study aimed to establish gender effects of cooperative learning on academic achievement of students in basic science. In contrast, the current study aimed to establish gender effect of Project-based learning on students' academic achievement and critical thinking skills.

Furthermore, Tisngati *et al.* (2019) conducted research to ascertain the effect of leaning methods towards students' achievement viewed from gender in Donorojo sub-district Pacinta, Indonesia. In their study, experimental method was adopted by implementing 2x2x2x2 factorial design. The populations of the study consist 206 students of the 7th grade of junior high school in which 111 were male students and 95 were female students. The students were selected using cluster random sampling. The instrument used for data collection was Normality and homogeneity test which was taken from student's mid examination score doing t-test. The final result was obtained from the final test scores of

mathematics learning on probability theory using the jigsaw cooperative learning method for the experimental group and conventional method for the control group. The data was analyzed using two-way variance analysis techniques with SPSS. The findings of the study revealed that there were no significant differences in student's mathematics achievement learning between male and female students. The difference between the existing study and the current study is that the existing study was carried out in Donorojo in Indonesia. In contrast to the current study which was carried out in Minna Nigeria.

Table 2.5: Summary of Gender and Achievement

Authors	**Research**	**Methodology**	**Instructional Content**	**Result**
Igbo and Oyibo (2015)	Impact of Gender Stereotype on Secondary School Students' Self-Concept and Academic Achievement	Ex post Factor Experimental design	Mathematics	The findings of the study revealed that Gender has a significant influence on student's academic achievement in favor of male students.
Nwaokolo *et al* (2019)	the comparative effects of individualized and cooperative video-based instructional strategies on secondary school students' achievement in Biology	Quasi experimental design	Biology	The findings of the study reveal that there is statistically significant difference between the mean scores of male and female students

Githae (2015)	the effects of Collaborative Concept Mapping Teaching Approach on secondary school biology student's achievement	Quasi experimental Design	Biology	The findings of the study revealed that gender has no significant difference on students' academic achievement.
Filgona *et al.* (2016)	Effect of Hands-On Learning Strategy on Senior Secondary School Students' Achievement in Topographical Map Studies in Mayo Belwa Local Government Area, Nigeria	Geography	Quasi experimental Design	The findings of the study revealed that there was no significant effect of gender on the achievement of students taught topographical maps using hands-on learning strategy.
Sheyin & Omolara (2018)	The effects of Computer-Based pedagogy on the achievement of pre-service teachers in an ecology	Experimental research design	Biology	The Result of the findings showed that there is no significant difference on the effect of gender on students academic achievement in ecology.
Olupide (2018)	Gender Effects Of Cooperative Learning On Academic Achievements Of Students In Basic Science In Ogun State, Nigeria	Quasi experimental design	Basic Science	The result showed that there was no significant difference between the academic achievement of the male and female students exposed to the cooperative learning strategy

Tisngati (2019)	The effect of fleaning methods towards students' achievement viewed from gender	Experimental research design	Mathematics	The findings revealed that there were no significant differences in student's mathematics achievement learning between male and female students

In view of the literatures reviewed under empirical studies, it has been seen that mixed method research design has been rarely used by other authors to ascertain the effect of PBLA approach on students CTS and ecological achievement, therefore, these studies have not been fully exploited hence, the reason the researcher has chosen to adopt the mixed method research design so as to ascertain an in-depth understanding of the problem and also strengthen the findings of the study. Also, in view of the foregoing, findings on gender and student's critical thinking skills and achievement are inconclusive, therefore gender is considered as a moderating variable in this study.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Design

For the purpose of this study, the researcher adopted a mixed method explanatory sequential design where the researcher used both quantitative and qualitative research approaches in the collection of data, analysis and inference in order to explore an in depth understanding of the study. According to Creswell and Clark (2018) mixed methods research design is a procedure for collecting, analyzing, and "mixing" both quantitative and qualitative research methods in a single study to solve a research problem. In this study, the mixed methods research designs will be factorial experimental design and phenomenology.

The quantitative data collected was to test the formulated hypothesis as highlighted in chapter one. The researcher utilized a factorial experimental design which allow the researcher to examine two or more independent variables or factors and each independent variable is examined on two or more levels (Creswell and Clark 2018). Hence, the 2*2 factorial experimental design was adopted and the independent variable are the two types of instructional approach used which include; Project-based learning method and lecture method while the second factor is students' academic achievement and critical thinking skills.

The researcher used phenomenology which aim to provide detailed examination of the experience of a phenomenon through participant's personal experience and personal perception of objects or events (Edwin *et al.* 2019). The qualitative data was used to understand students learning experience, how students learn ecology as well as critical thinking skill was acquired. Hence, the formulated hypothesis can be verified. The qualitative data collected was analyzed independently and combined during the

interpretation data and discussion of results. The mixed method explanatory sequential design is presented in figure 3.1

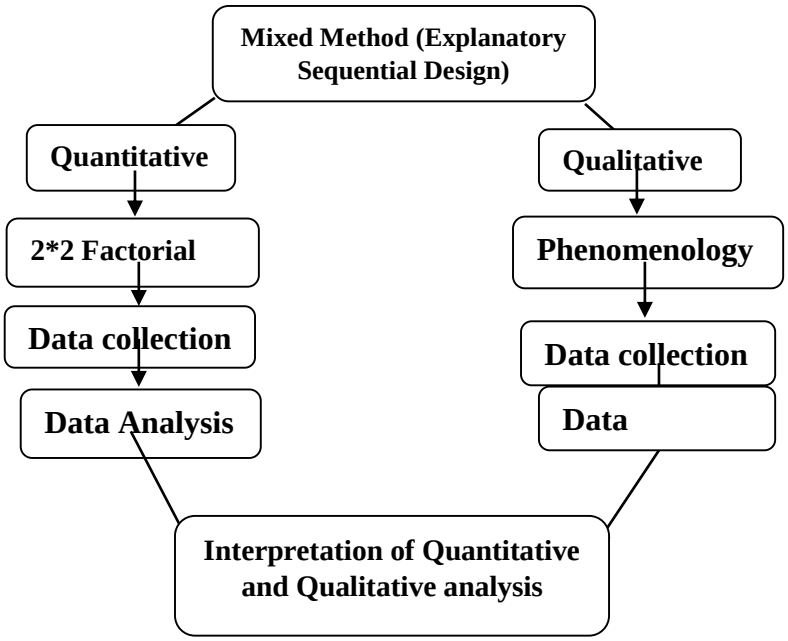

Figure 3.1. Mixed Method Explanatory Sequential Design adapted from Creswell & Creswell, (2018)

3.2 Population of Study

The population of the study was 29 senior secondary school biology students among government school in Minna, Niger state for 2020/2021 academic session. The target was Senior Secondary School class two (SSS2) biology students in Minna Niger state which comprises of 6,409 that is 3,125 Male and 3,284 Female (Niger State Ministry of Education, 2021). This was collected during the 2020/2021 academic session.

3.3 Sample and Sampling Technique

The sampling technique is divided into two phase which quantitative sampling and qualitative sampling.

3.3.1 Quantitative sampling technique

A sample size of 194 students which consist of 113 male and 79 female senior secondary school two biology student was selected for the study. The sample size was selected using central limit theorem which state that, if you take sufficiently large samples from a population, the samples' means will be normally distributed, even if the population isn't normally distributed. Hence the researcher used this theorem since is experimental research to select the samples.

Three Multistage sampling procedures was be adopted for the study. Firstly, cluster sampling was used to classify Minna into Chanchaga Local Government Area and Bosso Local Government Area. Secondly, Purposive sampling was used to select four schools, two school from each cluster. The purposeful selection of school was based on the following criteria: (a) Co-educational (b) Functional biology Laboratory (c) Functional Computer laboratory. Finally, the selected schools were randomly assigned into experimental and control group. Intact class will be used in the experimental and control group.

3.3.2 Qualitative sampling technique

A sample size of 10 students (5 males and 5 females) was selected using purposive sampling. The purposefully selection of students was based on the student's participation in the process of teaching and learning and students' ability.

3.4 Research Instruments

In this study three (3) research instrument were used to collect data. Two (2) instrument Biology Critical Thinking Skill Test (BCTST) and Ecology Achievement Test (EAT) were used to collect quantitative data while Interview Question Protocol (IQP) was used to collect qualitative data.

3.4.1 Biology Critical Thinking Test Instrument (BCTST)

The instrument used in collecting data in this study is Biology Critical Thinking Test Instrument (BCTST). The Biology Critical Thinking Test Instrument consist of two sections, Section A and B respectively. The section A requires the bio-data of the students while section B is the critical thinking test which is further divided into 4 sub-skills with a total of 20 items adapted from California Critical Thinking Skill Test (CCTST). The sub-skills are based on the Inference, Analysis, Interpretation and Evaluation. Each sub-skills have 5 items respectively and students are expected to draw conclusion from observed facts, identify relationships among statements or questions, comprehend and decide the correct conclusion to the statement and assess the credibility of a statement from a list of options provided. The scores of the students were scored by 5 marks for each question which gave a sum total of 100 based on their performance.

3.4.2 Ecology Achievement Test (EAT)

Ecology Achievement Test (EAT) on the other hand has consist of 30 multiple choice objective items adapted from past questions from West Africa examination council (WAEC) and National Examination Council (NECO). The Ecology Achievement Test (EAT) Instrument was based on SSS2 curriculum on concepts of Ecology. The Ecology Achievement Test Instrument consist of 2 sections. The first section (section A) obtained information on the student's class, School, age and sex, while the section B obtained information on the student's achievement in the content. In each of the multiple-choice questions there are 4 options; A, B, C, and D with only one option as the correct answer while the other option serves as distracters. The correct answer takes two marks while the wrong answer takes no mark. The scores were converted to percentage before using for analysis.

3.4.3 Interview question protocol (IQP)

The qualitative data was collected using interview questions protocol. The interview question protocol consists of open-ended questions which was used to collect students' opinion of the learning process using PBLA approach. In some occasions the questions were modified and recorded during the interview especially when the interviewee does not understand the question. The interview was conducted at the end of the intervention since the aim of the interview is to gather data on students' perspective on the entire process. Tessier (2012), reported that during interview data should be collected using tape recorder for proper data management. Hence the interview was recorded with the consents of the interviewee and the data from the interview seek to establish the process of critical thinking acquired by the learners during the implementation of PBLA. The interview section last for about 10 to twenty minutes for each student. The interview section will be friendly to encourage the interviewee to express their opinion freely. The recorded responses of the students will be transcribed and the data generated will be analyzed.

3.5 Validity of the Research Instruments

Three research instruments (BCTST, EAT, IQP) were validated using face and content validation.

3.5.1 Validity of biology critical thinking skill test (BCTST) instrument

Validity is the extents to which an instrument adequately represents the underlying construct that it ought to measure (Drost, 2011). The Biology Critical Thinking Test Instrument (BCTST) was subjected to expert validation. The thesis supervisors, two experts in the field of biology from the Department of Examination development, National Examination council (NECO) HDQTRS Minna, and one Reader from the Department of Counseling and Psychology, Ibrahim Badamasi University Lapai and two experienced Biology teachers from secondary schools. They validated the instruments

items on face and content validity. The face validation was logical arrangement of the items and the content validation was on the language and constructs used in the items. Furthermore, the experts examined the test instruments in terms of the appropriateness of the content, clarity and simplicity of the instruments, its suitability for the level of the students, as well as the extents to which the items cover the topic they are meant to cover and corrections were incorporated into the final form of instrument before administration.

3.5.2 Validity of ecology achievement test (EAT) instrument

Also, the Ecology Achievement Test (EAT) instrument was subjected to expert validation. The thesis supervisors, two experts in the field of biology from the Department of Examination development, National Examination council (NECO) HDQTRS Minna, and one Reader from the Department of Counseling and Psychology, Ibrahim Badamasi University Lapai and two experienced Biology teachers from secondary schools. They validated the instruments items on face and content validity. The face validation was logical arrangement of the items and the content validation was on the language and constructs used in the items. Furthermore, the experts examined the test instruments in terms of the appropriateness of the content, clarity and simplicity of the instruments, its suitability for the level of the students, as well as the extents to which the items cover the topic they are meant to cover and corrections were incorporated into the final form of instrument before administration.

3.5.3 Validity of the interview protocol

The qualitative instrument (open-ended interview question) was validated by the project supervisor and two other lecturers from the Department of Science Education, Federal University of Technology Minna. The interview question protocol items were validated on face and content validity. The face validation was the logical arrangement of the items

and the content validation deals with the language and the relevant of the interview questions to the aim of the study.

3.6 Reliability of the Research Instrument

Reliability of the Biology critical thinking skill test (BCTST) and Ecology Achievement Test (EAT) were measured using Cronbach's Alpha. Four reliability coefficient was obtained for BCTST research instrument because the instrument has four sub-skills.

3.6.1 Reliability of biology critical thinking skill test (BCTST) instrument

According to Drost (2011), reliability is the degree to which the measure of a construct is consistent or dependable. Hence, in order to determine the reliability of the instrument, a pilot study was carried out. A sample of fifteen (15) SSSI students were selected from St Clement Secondary school, Minna, a secondary school which did not take part in the actual research study. The students were allowed to work on the questions in order to determine the functionality and the feasibility application of the instrument in terms of clarity and simplicity of the words used, quality, language, relevance of the instrument and general attitude to the instruments.

A test re-test method was used to obtain two set of scores for the instrument BCTST. The both scores were analyzed using Cronbach's alpha. The reliability coefficients obtained for the BCTST under the sub skills; Inference, Analysis, Interpretation and Evaluation were 0.81, 0.74, 0.83, and 0.72 respectively. which were all within the range of high reliability coefficient. With this result the instrument was found reliable and suitable for the study.

3.6.2 Reliability of ecology achievement test (EAT) instrument

Also, a pilot study was carried out for EAT instrument. A sample of fifteen (15) SSS2 students were selected from St Clement Secondary school, Minna, a secondary school

which did not take part in the actual research study. The students were allowed to work on the questions in order to determine the functionality and the feasibility application of the instrument in terms of clarity and simplicity of the words used, quality, language, relevance of the instrument and general attitude to the instruments.

A test re-test method was used to obtain two set of scores for the instrument EAT. The both scores were analyzed using Cronbach's alpha. The reliability coefficients obtained for the EAT was 0.77, is within the range of high reliability coefficient. With this result the instrument was found reliable and suitable for the study.

3.7 Method of data Collection

3.7.1 Quantitative method of data collection

The researcher visited the selected schools to examine the facilities, the students and to determine their suitability for the research work and seek official permission and cooperation to use the schools and facilities from the respective college authorities. From the 4 sampled schools, two schools each was allocated to an experimental group and a control group. The researcher informed the staff and student about the objectives of the study. The subject teachers were brief about the Project-Based learning approach. The experimental group research assistant was guided on the necessary strategies for implementing treatment. The control group teachers were given instructions on how to conduct their class.

The study covered a period of Seven weeks. The objectives and modalities of the experiments was specified to the teachers. Afterwards, briefing and demonstration session on the procedure for carrying out the experiment was schedule for one week for the teachers. Before the commencement of the experiment during the second week, Biology critical thinking skill test (BCTST) and the biology achievement test (EAT) was administered as pre-test. The objective of administering the pre-test is to ascertain the

academic equivalents of the students in critical thinking skill and achievement before the commencement of the experiment. Treatment follow thereafter and lasted for four weeks. The post-test was administered immediately after the treatment to obtain the students' academic equivalent after treatment.

3.7.2 Treatment Phases

Students in the treatment group were divided into groups and all groups completed an eight-day problem-driven project grounded in ecology. It was connected to the real-world problem. The project design followed the seven-phase model in Bell (2010) suggested framework for project-based learning instruction implementation in the classroom. This research-based project culminated with student creation of a modeled product that reflected their learning and the development of plausible solutions to the problem extinction.

Phase 1 the Introduction: The researcher introduced students to the topic and provided a brief explanation on the topic and the problem question that guided their research.

Phase 2 the problem identification: Here the students identified and analyzed the problem. The students were able to identify the importance of solving the problem.

Phase 3 investigating the problem: The researcher provided students with laptops and access to links to the necessary websites and databases, as well as text books to gathered meaningful information and data. Students Generates scientific concept and principle that will be applied in solving the problem.

Phase 4 ascertaining possible solution: In this phase, the students formulated possible ways to solve the problem. Students Develop a plan and establish strategy to solve the problem. The students analyzed and synthesize their research.

Phase 5 design the project: in this phase, the students applied scientific concepts and principles to the design. the student makes sketches on paper to illustrate the design. The students then translate the sketches into a prototype based on the specification established during problem identification

Phase 6 presentation of the design: in this phase, Reflection, occurred when students reflected on their research and proposed solutions to their problem. Furthermore, there was a debriefing session in a whole class discussion format where students shared their discoveries, ideas, findings and thought on the overall experience. This is achieved through graphic, test, diagrams and through a model.

Phase 7 Evaluation: In the final phase, the students then provided feedback and reaction to the others group's presentation. Students evaluate their design process and prototype based on the specification. Learners reflect on the entire processes.

Table 3.1: Summary of Phases of Implementing PBLA

PBLA Phases	Sub- Phases	Task/Description
Introduction	Understand the problem	- Formulating the problem. - Analysis the problem by breaking down the fact into smaller segments. - Asking relevant questions for better understanding of the problem such as why and how questions.
Problem Identification	Brainstorming	- Analyzing the cause of the problem. - Identifying the importance of solving the problem.
Investigating the problem	Collaborating and research work	-Gathering meaningful information and data from text books, online materials and consulting expert in the field. - Generating scientific concept and principle that will be applied in solving the problem.
Ascertain Possible solutions	Exploration and Planning	- Formulation of possible ways to solve the problem - Develop a plan and establish strategy to solve the problem
Design the project	Sketch and convert the diagram to a prototype or model	- Application of scientific concepts and principles to the design. - Sketch to illustrate the design. - Translate the sketches into a prototype based on the specification established during problem identification.
Presentation of the Design	Share and defend your ideas and discoveries.	- Students share their discoveries, ideas and finings to other students in all phases. - This is achieved through graphic, test, diagrams and through a model
Evaluation	Evaluate the entire process of the design	- Students evaluate their design process and prototype based on the specification. - Learners reflect on the entire processes.

At the end of the treatment, post-test was administered Following completion of the intervention, the researcher assessed the students' performance on the activity with Biology critical thinking skill (BCTST) and Ecology achievement test (EAT) instrument.

3.7.3 Qualitative method of data collection

The qualitative data in this research study enhanced the understanding of the process of learning using PBLA approach as well as solicit for information that cannot be determined quantitatively using pre-test and post-test. The method of collection of quantitative data include interview. During the interview session the researcher had an open-ended face to face conversation with the students. The researcher used a phone recorder to collect data (responses) from the students one at a time. The process was done informally to enable the students speak freely. The questions were focused, clear and also encourages open ended response. Find extract from the interview session in the Appendix K.

Table 3.2: Summary of Quantitative and Quantitative Methods of Data Collection

Weeks	Activity
1	Briefing and demonstration section
2	Pre-test administration
3-5	Treatment
6	Post-test administration
7	Interview session

3.8 Method of Data Analysis

3.8.1 Quantitative method of data analysis

Two statistical tools were employed to analyze the scores obtained from the samples in BCTST and EAT (pre-test and post-test). The data obtained were analyzed using mean and standard deviation to answer the research questions, while Multivariate analysis (MANOVA) was used to test hypothesis 1, Analysis of variance will (ANOVA) was used to test hypothesis 3, 4 and 5 and Analysis of covariance will (ANCOVA) was used to test hypothesis 2 and 6.

Thematic content analysis was used to analyze the qualitative data from the students. The procedures for data analysis include; familiarization of the data, transcribing the data, coding and data interpretation.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The study investigated the effect of a project-based learning approach in enhancing critical thinking skills and achievement among secondary school biology students in Minna Niger state.

4.1 Results on Research Questions

To answer the research questions that guided this study, pretest and posttest data were used and the findings were presented based on research questions and the formulated hypotheses.

Research Question one: What is the difference in the mean score of secondary school students' critical thinking skills taught with Project-based learning and lecture method? To answer this research question, the mean and standard deviation was employed and the results are presented in Table 4.1

Table 4.1 Mean and Standard Deviation of Pre-test and Post-test Critical Thinking Skills results for students taught with Project-based and Lecture method.

Group		Post-test		Pre-test		Mean Gain	Mean Diff
		Mean	SD	Mean	SD		
Project-based	94	50.21	13.257	19.10	10.394	31.11	29.76
Traditional	100	22.10	7.823	20.75	7.013	1.35	

The result in Table 4.1 indicates the mean and standard deviation of the pre-test and post-test of project-based learning and lecture methods. The pre-test mean was 19.10 with standard deviation of 10.394 and 20.75 with standard deviation of 7.013, while the post-test mean was 50.21 with standard deviation of 13.257 and 22.10 with standard deviation

of 7.823 respectively. The two groups improved on their critical thinking skills. However, students that were taught with project-based learning approach had the highest mean gain of 31.11, while the control group has the least mean gain of 1.35.

Research Question Three: what is the main effect of gender on secondary school student's achievement in Ecology? To answer this research question, the mean and standard deviation was employed and the results are presented in Table 4.2

Table 4.2 Mean and Standard Deviation Pre-test and Post-test achievement results for Male and female Students.

Group		**Post-test**		**Pre-test**		**Mean Gain**	**Mean dff**
		Mean	**SD**	**Mean**	**SD**		
Exp Male	55	59.09	15.729	25.93	10.904	33.16	
Exp Female	39	53.71	13.262	24.68	8.759	29.03	4.13
Control Male	50	50.61	13.105	30.80	10.426	19.81	
Control Female	50	44.65	12.532	28.59	12.654	16.06	3.74
Total	194	52.10	14.722	27.62	11.047	24.48	

The result in table 4.2 Indicates the mean and standard deviation of the pre-test and post-test score of male and female students taught using PBLA. The pre-test mean score of male and female students in the experimental group were 25.93, 24.68 with standard deviation of 10.904, and 8.759, respectively. While the post-test score of male and female students in the experimental group were 59.09 and 53.71 with a standard deviation of 15.729 and 13.262 respectively.

The pre-test score of the male and female students in the control group were 30.80 and 28.59 with a standard deviation of 10.426, and 12.659 respectively. while the post-test

score of the control group were 50.61, 44.69 and standard deviation of 13.105 and 12.532 respectively. From the result, the mean difference between the male experimental and female experimental is 4.13 in favour of male student. Similarly, the mean difference between the control male and female is 3.75 in favour of the male students.

Research Question Four: What is the interaction effect of the independent variables and gender on critical thinking skills? To answer this research question, an interaction graph is presented in Figure 4.1

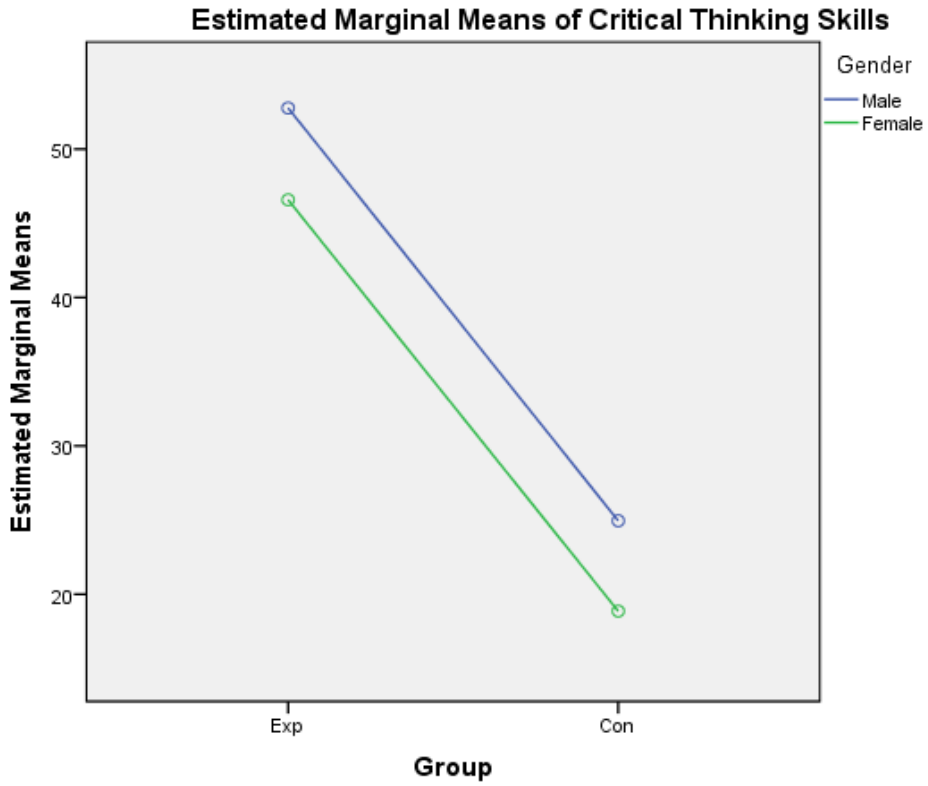

Figure 4.1: Interaction effect of project-based learning and gender on critical thinking skills

The result suggested that the instructional approach (project-based learning and lecture method) and students critical thinking skills did not interact in a manner that could influence critical thinking skills development among students. Furthermore, the mean and standard deviation of male and female students is presented in Table 4.3

Table 4.3: Interaction effect of Mean and Standard Deviation Pre-test and Post-test Critical Thinking Skill results for Male and Female Students.

Group		Post-test		Pre-test		Mean Gain	Mean dff
		Mean	SD	Mean	SD		
Exp Male	55	52.73	13.738	17.82	10.081	34.91	
Exp Female	39	46.67	11.828	20.90	10.691	25.77	9.14
Control Male	50	25.00	6.999	20.00	9.583	5.00	
Control Female	50	18.80	8.425	17.30	9.379	1.50	3.5
Total	194	35.62	17.927	18.87	9.935	16.75	

The result in table 4.3 Indicates the interaction effect of mean and standard deviation of the pre-test and post-test score of male and female students taught using PBLA. The pre-test mean score of male and female students in the experimental group were 17.82, and 20.90 with standard deviation of 10.081, and 10.691, respectively. While the post-test score of male and female students in the experimental group were 52.73 and 46.67 with a standard deviation of 13.738 and 11.828 respectively. The pre-test score of the male and female students in the control group were 20.00 and 17.30 with a standard deviation of 9.583, and 9.379 respectively. While the post-test score of the control group were 25.00, and 18.80 and standard deviation of 6.999 and 8.425 respectively. From the result, the mean difference between the male experimental and female experimental is 9.14 in favour of male student. Similarly, the mean difference between the control male and female is 3.5 in favour of the male students.

Research Question Five: What is the main effect of PBLA on secondary students' achievement in ecology? To answer this research question, the mean and standard deviation was employed and the results are presented in Table 4.4

Table 4.4 Comparison of Mean and Standard Deviation Pre-test and Post-test achievement results for students taught using Project-based, and Lecture method

Group		Post-test		Pre-test		Mean Gain	Mean Diff
		Mean	SD	Mean	SD		
Project-based	94	56.85	14.921	27.66	23.765	29.19	11.25
Traditional	100	47.63	13.104	29.69	11.558	17.94	

The result in table 4.4 indicates the mean and standard deviation of the post-test and pre-test achievement test taught using project-based learning approach and lecture methods. The post-test mean of the PBLA and lecture methods were 56.85 and 47.63 with standard deviation of 14.921 and 13.104 respectively while the pre-test mean were 27.66, and 29.69 with a standard deviation of 23.765 and 11.558 respectively. The two groups improve in their ecology achievement. However, students that learn with project-based learning approach had the mean gain of 29.19, while those taught using lecture method has the least mean gain of 17.94. This indicates that the students introduced to project-based learning approach performed better than those taught with the lecture method with a mean difference of 11.25. The findings indicate that project-based learning approach effectively enhance students' performance in ecology than the lecture method. Inferential statistics were used to compare the posttest mean.

Research Question Seven: what is the interaction effect of independent variable and gender secondary school student's achievement in ecology? To answer this research question, an interaction graph is presented in Figure 4.2

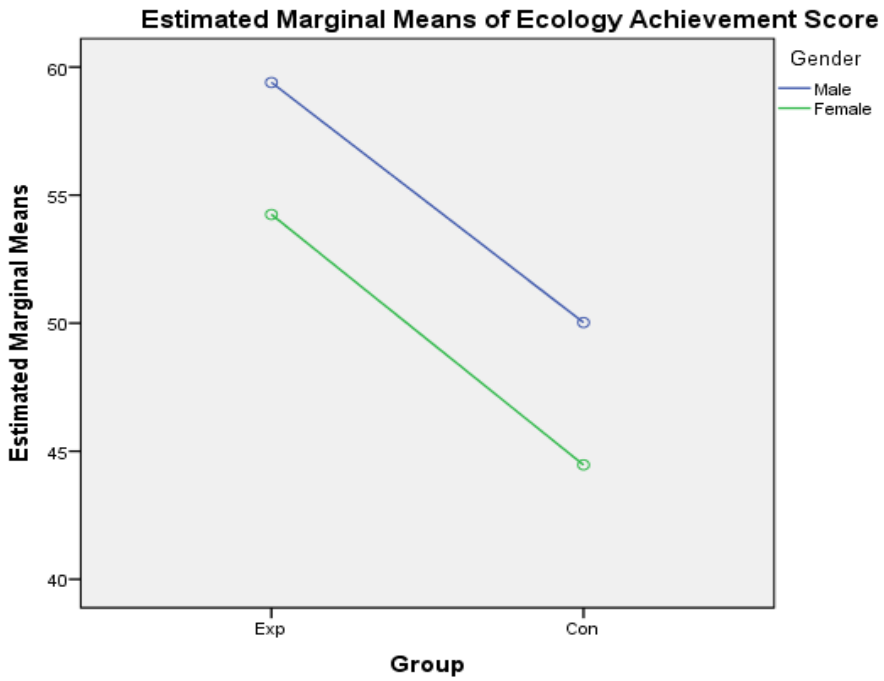

Figure 4.2: Interaction effect of project-based learning and gender on student achievement in ecology.

The result suggested that the instructional approach (project-based learning and lecture method) and students' achievement in ecology did not interact in a manner that could influence academic achievement in ecology among students. Furthermore, the mean and standard deviation of male and female students is presented in Table 4.5

Table 4.5: Interaction effect of Mean and Standard Deviation Pre-test and Post-test achievement results for Male and female Students.

Group		Post-test		Pre-test		Mean Gain	Mean dff
		Mean	SD	Mean	SD		
Exp Male	55	59.09	15.729	25.93	10.904	33.16	
Exp Female	39	53.71	13.262	24.68	8.759	29.03	4.13
Control Male	50	50.61	13.105	30.80	10.426	19.81	
Control Female	50	44.65	12.532	28.59	12.654	16.06	3.74
Total	194	52.10	14.722	27.62	11.047	24.48	

The result in table 4.5 indicates the interaction effect of mean and standard deviation of the post-test and pre-test of achievement test using project-based learning approach and lecture methods. The post-test mean score of male and female students in the experimental group were 59.09 and 53.71 with a standard deviation of 15.729 and 13.262 respectively while the pre-test mean score of male and female students in the experimental group were 25.93 and 24.68, with a standard deviation of 10.904 and 8.759 respectively. The post-test mean of male and female student in the control group were 50.61 and 44.65 with a standard deviation of 13.105 and 12.532 respectively while the pre-test mean was 30.80 and 28.59 with a standard deviation of 10.426 and 12.654 respectively. From the result it shows that the male students performed better in their achievement test than female students with a mean difference of 4.13. similarly, the mean difference between the control male and control female is 3.74 in favour of the male students.

Research Question Eight: what is the main effect of gender on secondary school student's critical thinking skills? To answer this research question, the mean and standard deviation was employed and the results are presented in Table 4.6

Table 4.6: Mean and Standard Deviation Pre-test and Post-test Critical Thinking Skill results for Male and female Students taught using Project-based, and Lecture method

Group		Post-test		Pre-test		Mean Gain	Mean dff
		Mean	SD	Mean	SD		
Exp Male	55	52.73	13.738	17.82	10.081	34.91	9.14
Exp Female	39	46.67	11.828	20.90	10.691	25.77	
Control Male	50	25.00	6.999	20.00	9.583	5.00	4.03
Control Female	50	18.00	8.425	17.30	9.374	0.7	
Total	194	35.62	17.927	18.87	9.935	16.75	

The result in table 4.6 indicates the mean and standard deviation of the post-test and pretest of critical thinking skill test using project-based learning approach and lecture methods. The post-test mean of male and female students taught using project-based learning approach were 52.73 and 46.67 and the pre-test mean were 17.82, and 20.90, respectively, while the post-test mean of male and female student taught using lecture method were 25.00 and 18.00 and pre-test mean were 20.00 and 17.30 respectively. This shows that the male students are better than the female students in critical thinking skill with a mean difference of 9.14 in the PBLA group. Similarly, in the traditional group the male students had the highest mean gain of 5.00 with a mean difference of 4.03.

4.2 Results on Null Hypotheses

This section deals with data analysis to test the formulated null hypotheses, as highlighted in chapter one. However, before testing the hypotheses, pre-test analysis was conducted to determine the equivalence of the group before treatment.

4.3 Pre-test Result

The pre-test data were analyzed using an independent t-test to determine whether the project-based learning and traditional group were equivalent in all the sub-section and the overall score in ecology before the intervention. The result is as displayed in Table 4.7

Table 4.7: Pre-test independent t-test Analysis of Secondary School Students' Critical Thinking skills taught with Project-based Learning and Traditional Group

Group	N	Mean	SD	*df*	t-value	p-value	Decision
Project-based	94	19.10	10.394	192	0.312	0.76	Not Significant
Traditional	100	18.65	9.531				

Table 4.7 result t(192)=0.312, p=0.76 (p>0.05) shows there is no significant difference in the pre-test critical thinking skills of students in Project-based learning and traditional group. Indicating that the two groups: project-based learning and the traditional groups were comparable before intervention. Therefore, two-way factorial ANOVA was used to analysed the post-test data to determine the main effect and interaction effects of treatment and gender.

Table 4.8 Pre-test independent t-test Analysis of Secondary School Students' biology Achievement taught with Project-based Learning and Traditional Group

Group	N	Mean	SD	*df*	t-value	p-value	Decision
Project-based	94	25.41	10.038	192	-2.74	0.01	Significant
Traditional	100	29.69	11.588				

Table 4.8 result t(192)=-2.74, p=0.01 (p<0.05) shows that there is a significant difference in the biology achievement scores of students in Project-based learning and traditional

group. Indicating that the two groups: project-based learning and the traditional groups were not comparable before intervention. Therefore, ANCOVA was used to analysed the post-test data to determine the main effect and interaction effects of treatment and gender.

Hypothesis One (HO_1): There is no significant main effect of PBLA on secondary school students critical thinking skills. To test this formulated hypothesis, Multivariate Analysis of Variance (MANOVA) was used and the results are presented in Table 4.9.

Table 4.9: Post-test MANOVA Result 0f Critical Thinking Sub-Skills of project-based learning and Lecture method.

Effect		Value	F-value	Hypothesis *df*	Error *df*	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.914	402.095[b]	5.000	188.000	.000	.914
	Wilks' Lambda	.086	402.095[b]	5.000	188.000	.000	.914
	Hotelling's Trace	10.694	402.095[b]	5.000	188.000	.000	.914
	Roy's Largest Root	10.694	402.095[b]	5.000	188.000	.000	.914
Group	Pillai's Trace	.646	68.676[b]	5.000	188.000	.000	.646
	Wilks' Lambda	.354	68.676[b]	5.000	188.000	.000	.646
	Hotelling's Trace	1.826	68.676[b]	5.000	188.000	.000	.646
	Roy's Largest Root	1.826	68.676[b]	5.000	188.000	.000	.646

Table 4.9 Result wilk's Λ =.354, F (5, 188) = 68.676, P= (0.00) < 0.05, partial n^2 =0.646 shows that the result of the MANOVA yielded that there was a statistically significant difference between the two groups, project-based learning and traditional on the combined dependent variables. Based on these results, evidence was sufficient to reject the null hypothesis and conclude that students critical thinking skills as measured by the BCTST significantly differed based on the type of teaching method used to teach the student. The multivariate partial n^2 of 0.647 indicates that 64.7% of the total multivariate variances in CTS above is attributed to the effect of treatment.

Considering the fact that the results were significant, we need to look at the between-subject effect of each dependent variable. The result is presented in the table 4.10 below.

Table 4.10 Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	*df*	Mean Square	F-value	Sig.	Partial Eta Squared
Intercept	Inference	82378.816	1	82378.816	430.470	.000	.692
	Analysis	170398.856	1	170398.856	835.637	.000	.813
	Interpretation	335407.505	1	335407.505	1325.721	.000	.873
	Evaluation	498699.961	1	498699.961	1406.111	.000	.880
	Total	249486.587	1	249486.587	1995.752	.000	.912
Group	Inference	6444.795	1	6444.795	33.677	.000	.149
	Analysis	28147.309	1	28147.309	138.035	.000	.418
	Interpretation	65617.814	1	65617.814	259.359	.000	.575
	Evaluation	78502.023	1	78502.023	221.341	.000	.535
	Total	39236.072	1	39236.072	313.867	.000	.620
Error	Inference	36742.963	192	191.370			
	Analysis	39151.660	192	203.915			
	Interpretation	48576.000	192	253.000			
	Evaluation	68095.915	192	354.666			
	Total	24001.686	192	125.009			
Total	Inference	124225.000	194				
	Analysis	233600.000	194				
	Interpretation	440800.000	194				
	Evaluation	633600.000	194				
	Total	306875.000	194				

When table 4.10 is examined, it is seen that there is a significant difference between the critical thinking skill inference sub-skill adjusted post-test mean scores of the experimental group and control group F (1, 192) = 33.677, P = (.00) < 0.05, partial n^2 = 0.149. This difference is between the experimental group sub-skill inference and those of the traditional group. When the adjusted arithmetic mean of the groups are examined, it is seen that the significant difference was in favour of the project-based learning group. The partial n^2 of 0.149, indicates that 14.9% of the variance in inference subskill is due to treatment.

The result also indicates that there is a significant difference between the critical thinking skill analysis sub-skill adjusted post-test mean scores of the experimental group and control group. F (1, 192) = 138.035, P = (.00) < 0.05, partial n^2 = 0.418. This difference

is between the experimental group sub-skill analysis and those of the traditional group. When the adjusted arithmetic mean of the groups are examined it is therefore seen that the PBLA was more effective in enhancing the subskill analysis than the lecture method. The partial n^2 of 0.418, indicates that 41.8% of the variance in inference subskill is due to treatment.

The result further shows that there is a significant difference between the critical thinking skill interpretation sub-skill adjusted post-test mean scores of the experimental group and control group. F (1, 192) = 259.359, P = (.00) < 0.05, partial n^2 = 0.575. This difference is between the experimental group sub-skill interpretation and those of the traditional group. When the adjusted arithmetic mean of the groups are examined, it is seen that the significant difference was in favour of the project-based learning group. The partial n^2 of 0.575, indicates that 57.5% of the variance in inference subskill is due to treatment.

The result also indicates that there is a significant difference between the critical thinking skill evaluation sub-skill adjusted post-test mean scores of the experimental group and control group. F (1, 192) = 221.341, P = (.00) < 0.05, partial n^2 = 0.535. This difference is between the experimental group sub-skill evaluation and those of the traditional group. When the adjusted arithmetic mean of the groups are examined, it is seen that the significant difference was in favour of the project-based learning group. The partial n^2 of 0.535, indicates that 53.5% of the variance in inference subskill is due to treatment.

Hypothesis Two (HO_2): There is no significant main effect of gender on secondary school student's critical thinking skills. To test this formulated hypothesis, ANCOVA was used and the results are presented in Table 4.11 below;

Table 4.11: ANCOVA Result for the Main Effect of Gender on Critical Thinking Skills

Source	TypeIII Sumof Squares	*df*	Mean Square	F-value	Sig.	Partial Eta Squared
Corrected Model	40640.20[a]	3	13546.73	120.36	.000	.655
Intercept	244617.14	1	244617.14	2173.30	.000	.920
pre-test (covariate)	36871.64	1	36871.64	327.59	.000	.633
Gender	1793.34	1	1793.34	15.93	.000	.077
Group * Gender	.232	1	.232	.002	.964	.000
Error	21385.58	190	112.556			
Total	308150.00	194				
Corrected Total	62025.77	193				

Results in Table 4.11 shows the effect of gender on ecology achievement. The value F (3, 190) = 15.93, P= (0.00) < 0.05, partial n^2 = .077 indicates that there is a significant difference in the critical thinking skill test scores of male and female students. Therefore, the hypothesis was rejected. The partial n^2 (.077) shows that 7.7% of the variance in critical thinking skills can be attributed to the treatment.

Hypothesis Three (HO_3): There is no significant interaction effect of the independent variables and gender on critical thinking skills. To test this formulated hypothesis, two-way ANOVA was used and the results are presented in Table 4.12

Table 4.12: Two-way ANOVA Result for Interaction Effect of the Independent Variables and Gender on Critical Thinking Skills

Source	TypeIII Sum of Squares	*df*	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	40640.20[a]	3	13546.73	120.36	.000	.655
Intercept	244617.14	1	244617.14	2173.30	.000	.920
Group	36871.64	1	36871.64	327.59	.000	.633
Gender	1793.34	1	1793.34	15.93	.000	.077
Group * Gender	.232	1	.232	.002	.964	.000
Error	21385.58	190	112.556			
Total	308150.00	194				
Corrected Total	62025.77	193				

Results in Table 4.12. shows the interaction effect of project-based learning and gender on critical thinking skills. The value F (3, 190) = .022, P= (0.96) > 0.05, partial n^2 = 0.00

indicates that there is no significant interaction effect between the mean of the combine effect of the independent variable and gender on critical thinking skill. Therefore, the hypothesis was accepted. The partial n^2 (.000) shows that 0.0% of the variance in critical thinking skills is not attributed to the interaction between the independent variable and gender. The interaction effect is further presented in a graphical form in figure 4.3

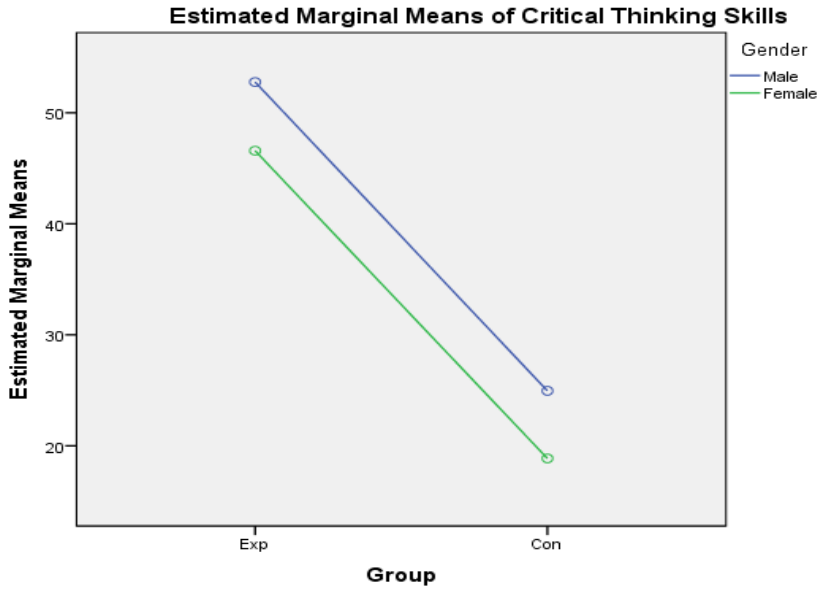

Figure 4.3: Interaction effect of project-based learning and gender on critical thinking skills

The result shows that the instructional approach (project-based learning and lecture method) and students' gender did not interact in a manner that could influence critical thinking skills development among students.

Hypothesis four (HO_4): There is no significant main effect of PBLA on secondary students' achievement in ecology. To test this formulated hypothesis, two-way ANOVA was used and the results are presented in Table 4.13

Table 4.13: Two-way ANOVA Result for the effect of Project-Based Learning and Lecture method on Ecology Achievement

Source	Type III Sum Of Squares	*df*	Mean Square	F-value	Sig.	Partial Eta Squared
Corrected Model	6434.549[a]	3	1608.637	8.590	.000	.154
Intercept	56790.398	1	56790.398	303.257	.000	.616
Pretest (covariate)	759.749	1	759.749	4.057	.045	.021
Group	4202.773	1	4202.773	22.443	.000	.106
Gender	1360.240	1	1360.240	7.264	.008	.037
Group * Gender	1.949	1	1.949	.010	.919	.000
Error	35393.740	189	187.268			
Total	568392.570	194				
Corrected Total	41828.290	193				

a. R Squared = .154 (Adjusted R Squared = .136)

Results in Table 4.13 shows post-test findings of project-based learning and traditional instructional strategies. The value F (4, 189) = 22.443, P= (0.00) < 0.05, partial n^2 = 0.106 indicates a significant difference between the mean of the project-based learning and traditional group achievement in ecology. Therefore, the hypothesis was rejected. The partial n^2 of 0.106, indicates that 10.6% of the variance in ecology achievement is due to treatment.

Hypothesis five (HO_5): There is no significant interaction effect of the independent variable and gender on students' achievement in ecology. To test this formulated hypothesis, two-way ANOVA was used and the results are presented in Table 4.14

Table 4.14: Two-way ANOVA Result for Interaction Effect of Gender on Project-Based Learning and Ecology Achievement

Source	Type III Sum of Squares	*df*	Mean Square	F-value	Sig.	Partial Eta Squared
Corrected Model	6434.549[a]	3	1608.637	8.590	.000	.154
Intercept	56790.398	1	56790.398	303.257	.000	.616
Pretest (covariate)	759.749	1	759.749	4.057	.045	.021
Group	4202.773	1	4202.773	22.443	.000	.106
Gender	1360.240	1	1360.240	7.264	.008	.037
Group * Gender	1.949	1	1.949	.010	.919	.000
Error	35393.740	189	187.268			
Total	568392.570	194				
Corrected Total	41828.290	193				

a. R Squared = .154 (Adjusted R Squared = .136)

Results in Table 4.14 shows the interaction effect of project-based learning and gender on student achievement in ecology. The value F (4, 189) = .010, P= (0.92) > 0.05, partial n^2 = 0.000. indicates that there is no significant difference between the mean of the independent variable and gender on student achievement in ecology. Therefore, the hypothesis was accepted. The partial n^2 = 0.00. indicates that 0.00% of the variance shows that there is no combine interaction between gender and the instructional strategy. The interaction effect is further presented in a graphical form in figure 4.4

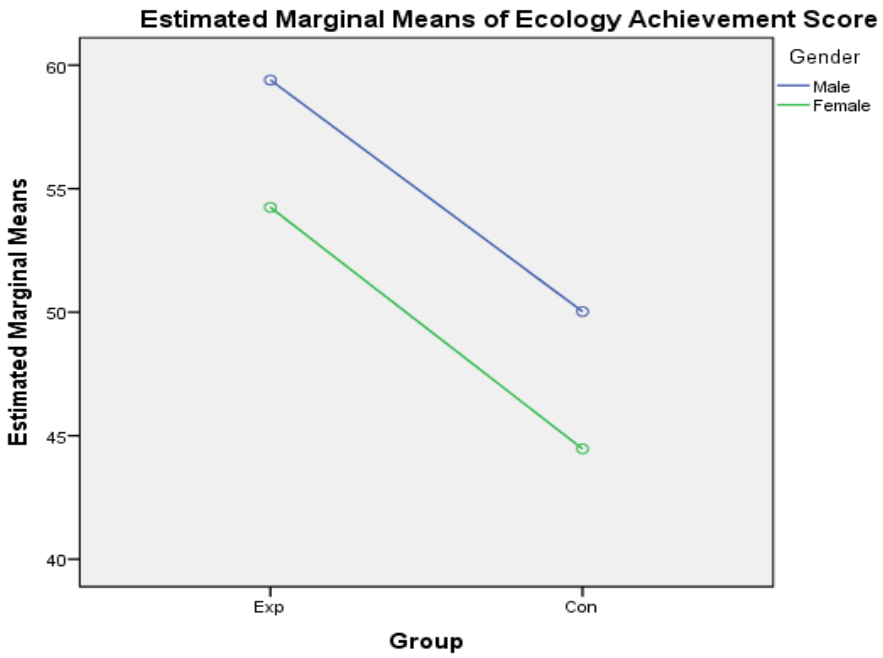

Figure 4.4: Interaction effect of project-based learning and gender on student achievement in ecology.

The result show that the instructional approach (project-based learning and lecture method) and gender did not interfere in a manner that could influence academic achievement in ecology among students.

Hypothesis Six (HO_6): There is no significant main effect of gender on secondary school students' achievement in ecology. To test this formulated hypothesis, ANCOVA was used and the results are presented in Table 4.15

Table 4.15: Factorial ANCOVA Result for Effect of Gender on Project-Based Learning and Ecology Achievement

Source	Type III Sum of Squares	*Df*	Mean Square	F-value	Sig.	Partial Eta Squared
Corrected Model	6434.549[a]	3	1608.637	8.590	.000	.154
Intercept	56790.398	1	56790.398	303.257	.000	.616
Pretest (covariate)	759.749	1	759.749	4.057	.045	.021
Group	4202.773	1	4202.773	22.443	.000	.106
Gender	1360.240	1	1360.240	7.264	.008	.037
Error	35393.740	189	187.268			
Total	568392.570	194				
Corrected Total	41828.290	193				

a. R Squared = .154 (Adjusted R Squared = .136)

Results in Table 4.15 shows effect of gender on ecology achievement. The value F (4, 189) = 7.264, P= (0.08) > 0.05, partial n^2 = 0.037 indicates that there is no statistically significant difference in the ecology achievement scores of male and female students. Therefore, the hypothesis was accepted. The partial n^2 (.037), indicates that 3.7% of the variance in ecology achievement can be attributed to the influence of gender.

4.4 Qualitative Results

The data from interviews and classroom observation was collected and thematic analysis was used to answer research question two and six as presented in this section.

Research Question Two: How does secondary school student acquire critical thinking skills when taught using Project-based learning approach? To answer this question, qualitative data in form of interviews was collected, thematic analysis was employed and the data from the oral discussion revealed that several process such discussion, brainstorming sessions, interaction, creating plans for solving problems are possible ways students acquire critical thinking.

The qualitative data reveals that PBLA effectively bridges the gap between theoretical and practical education, promoting students critical thinking. From the data collected it was seen that students participated actively in developing the project, researching, brainstorming, and sharing ideas which could have promoted cognitive ability of the students to interpret, analyze, make inference, and evaluate. The activities suggest that the students actively engage in the learning, hence the process were grouped under a theme active engagement and the sub-themes include collaborative learning and hands-on and minds-on activity.

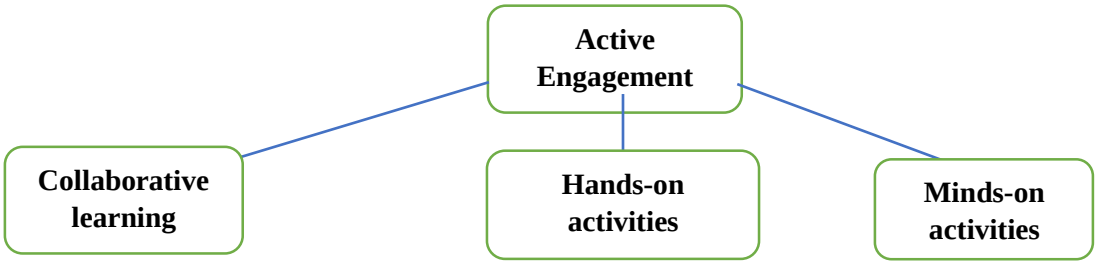

Figure 4.5: Collaborative Learning

This involves students' engagement in social learning through sharing of ideas, researching online, and brainstorming. The students interview response provided evidence to indicate that they engaged in peer-tutoring, collaboration, team-work, among others. This was demonstrated in the verbal excerpts below;

I and my group members work together to gather information from text books and online to solve the problem given to us.

(Chiamaka Interview 5/9/2022)

The new skills I learnt is group work, how to cooperate with my group that is team work because all the project I have done I usually do it alone so coming together to work as a group has helped me to cooperate with other people, brainstorm and bring different idea together.

(Mohammed Interview 5/9/2022)

I have learnt construction skills, team work creativity and also intellectual skills and logic reasoning.

(Zainab Interview 5/9/2022)

In this phase of interview, we could see that PBLA provides students the opportunity to work together as group to solve the problem, by so doing students questioned each other and challenge each other's mental shortcuts. This learning style ensures the students remain engaged in the content while thinking critically and sharing ideas with their peers.

Hands-on Activity

This involves students mental and physical engagement in social learning through creating a project. By creating a project, the students participated actively in the process using all of their senses. The students interview response provided evidence to indicate that they engaged in creativity. This was demonstrated in the interview excerpts below;

The construction aspect, where we were able to build a paper craft aquarium was fun because it requires us to think and find out more on habitat so our fish can survive in the aquarium and also procreate to prevent extinction of that specie.

(Ibrahim Interview 5/9/2022)

The part like was the part we had to source for construction items to create an aquarium, though it was fun, but it was stressful for me.

(James Interview 5/9/2022)

Constructing our model was very interesting. I and my group were able to come up with different ideas that lead to the creation of a beautiful project.

(Jemila Interview 5/9/2022)

The Following pictures provided evidence that learners were actively engage in the learning process through hands-on activities such as measuring, cutting and constructing among others as indicated in the pictures below

Plate I: Hand-on activities.

Minds-on Activity

These are learning activities that engage learners' Higher Order Thinking Skills (HOTs).

Interviews transcript indicated that that the learners were involved in minds-on activities

such as reasoning, analysing assertions, and proposing alternatives among others. These verbal transcripts mirror the engagement of higher mental processes as indicated by the following codes.

In constructing our aquarium, we generated a lot of ideas, evaluate each idea and later reject some idea. All of us in the group agreed on how our aquarium will look like

(chiamaka Interview 5/9/2022)

"we met in the group we were able to analyze the problem and that help me to understand what is needed to solve the problem"

(Ibrahim Interview 5/9/2022)

In my group we were able to bring out ideas that lead to the construction of our aquarium. Though some of the ideas were reconstructed to fit into the model created.

(Jibril Interview 5/9/2022)

From the student's response it shows that PBLA provides student the opportunity to create something with their hands and using their brain in thinking about what is going on around them as he or she tries to learn science. All this active involvement makes a powerful combination that dramatically enhance critical thinking. These findings supported the quantitative data presented earlier that showed that the mean score of students critical thinking skills taught using project-based learning approach is higher than those taught using the lecture method.

Research Question Six: How does secondary school students learn Ecology? To answer this question, qualitative data in form of interviews was collected, thematic analysis was employed. The data shows that under a project-based learning strategy the students, were faced with a problem to solve, and the process involved creating a project, performing a scientific investigation using different scientific methods such as brainstorming and generating different ideas to solve problem. This process seems to enhance their attitudes and motivation to learn ecology, hence the process was grouped under a theme learning experience and the sub-themes include learning satisfaction and learning attitude.

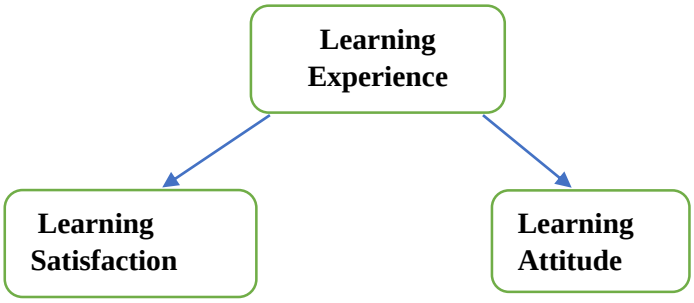

Figure 4.6: Interaction effect of interaction effect of project-based learning and gender on student achievement in ecology

Learning Satisfaction

Learning satisfaction involves the attitude resulting from an assessment of student's educational experience, service and facilities provided. The students interview response provided proof to indicate that they were satisfied with the whole process of learning. This was demonstrated in the interview excerpts below.

My experience thus far has been so great learning with project-based learning because it gave me a brighter view on ecology and not just that, how to put it in to work, through various constructive skills.

(Zainab Interview 5/9/2022)

I will like the teaching process to be brought to class and be taught more frequently because it is an interesting method of teaching and I had so much fun while learning and I will never forget what I have learnt.

(Jibril Interview 5/9/2022)

My experience was quite interesting because it was educative and it gives me more understanding on certain thing about ecology.

(Festus Interview 5/9/2022)

From the exerts it shows that students were satisfied with the whole process and not only dose satisfaction improve students' academic achievement, it also promotes students' mental health and stability which are necessary for long-term and short-term learning goals as well as character building. These findings supported the quantitative data presented earlier that showed that the mean score of students' academic achievement taught using project-based learning approach is better than those taught using the lecture method.

Learning Attitude

Learning attitude includes a range of consistent learning behaviors which demonstrate the aspiration of students to achieve their best. This includes engagement, effort, collaboration, active involvement among others. The students interview response provided evidence that students had right attitude towards learning ecology, this was demonstrated in the excerpts below;

The new skills I learnt is group work, how to cooperate with my group that is team work because all the project I have done I usually do it alone so coming together to work as a group has helped me to cooperate with other people, brainstorm and bring different idea together.

(Festus Interview 5/9/2022)

My experience was wonderful, and I will love the teachers to bring more of the practical lessons to the classroom so that students will understand better and do better academically.

(Titus Interview 5/9/2022)

My experience with project-based learning is wonderful, I enjoyed every aspect of the learning because I learnt new things that I don't know before. I will love this method of teaching to be brought into our school so that other students can benefit from it and it should not only be in biology it should be in all the subject so that learning would be easy for us.

(Zainab Interview 5/9/2022)

From the excerpts, it shows that student's attitude towards learning is associated with academic achievements. A positive attitude will enhance positive outcome academically while a negative attitude will limit students' performance academically and inhibits learning. These findings also supported the quantitative data presented earlier that showed that the mean score of students' academic achievement taught using project-based learning approach is better than those taught using the lecture method.

4.5 Discussion of Results

The established pattern in science learning is to help learners develop important skills and to have a deeper understanding through integrative approach similar to how science is practiced in a real-life scenario. The pattern of learning involves the combination of

critical thinking activities with that of science content knowledge that will help learners with the necessary knowledge and skills to be successful in the 21st century. Hence these research study explore the effect of enhancing secondary school students critical thinking skills and ecology achievement. Gender serves as a moderating variable.

Quantitative and qualitative data were collected concurrently and analyzed. The findings from the quantitative and qualitative data shows that project-based learning approach is a worthy instructional approach for enhancing students critical thinking skills as well as improving their achievement in ecology.

The findings of the studies were discussed as follows;

The finding of this study revealed that there was statistically significant difference in the critical thinking ability test scores of secondary school Biology students taught with project-based learning method and lecture method. The test scores were in favour of those exposed to project-based learning method. This is in support of the findings of Purba (2015) and Hanif *et al.,* (2018) who carried out research on enhancing students' creativity and critical thinking ability using project-based learning approach. It was revealed that student taught using PBLA performed better than those taught using conventional method. It also concurs with the study of Astra (2019) who investigated the effect of project-based learning model assisted by student's worksheet on critical thinking abilities of high school students. The findings revealed that students who were taught using PBLA model assisted by student's worksheet had an average score of critical thinking skill of 74.57 higher than students who were taught using traditional model with an average score of critical thinking skill of 61.29. The findings revealed that as a result of the study, the effect of the method applied for each dependent variable was found to favor the experimental group.

The thematic analysis also revealed that students demonstrated the ability to infer, analyzed, interpret and make evaluation. In this study, project-based learning provides an environment that engaged students in these cognitive processes. The elements, phases and activities in the project-based learning method helped the students to improve in critical thinking skills. This finding is supported with the report of Jamali *et al*, (2017) PBLA exposes students with real life, multidisciplinary problems that require critical thinking, hands on activities and collaboration. Firstly, for student to acquire critical thinking a problem question must be stimulated Larmer (2014) the most essential elements of PBLA is a significant, authentic driving question that is connected to real world. For example, in the present study, the problem scenario was to create a model habitat to prevent the extinction of a hybrid specie of a tilapia. This leads the students to develop a challenging and sustained inquiry to encourage them to think deeply and critically about the knowledge and understanding the content (Boss *et al*. 2015). Hence, students' higher cognitive ability was stimulated to view the problem from different perspective. This problem encourages the students to develop different ideas to solve the problem thus in the process developing their critical thinking ability.

Furthermore, the finding also showed that there was a statistically significant difference in the achievement scores of male and female senior secondary school Biology students taught with PBLA. The findings showed the male students performed better than the female students in the achievement scores. This is in support of the findings of Nwaokolo *et al* (2019) who carried out study on the comparative effects of individualized and comparative video based instructional strategies on secondary school students' achievement in biology. Results of the findings revealed a significant difference in the post-test scores between males and females in favour of the male taught with comparative video based instructional strategies. Also, in line with the findings of Igbo and Oyibo

(2015) who examined the impact of gender on secondary school students' self-concept and academic achievement in mathematic. The results showed that gender contribute significantly to varying students' achievement scores in favour of the male.

Also, Findings concerning the interaction effect of the independent variable and gender on Critical thinking skills shows that there is no significant interaction effect of PBLA and gender on critical thinking skill. There for students' improvement on critical thinking skill is solely attributed to the effect of the instructional method used. The analysis also indicates that there was statistically significant difference in the mean academic achievement test scores of secondary school Biology students taught ecology with project-based learning method and lecture method. This is in agreement with the study of Retnaningsih and Nugrahaningsih (2019) that investigated the effectiveness of project-based learning model and assessment of learning outcomes against portfolio. The findings of the study showed that learning achievement of students taught motion system with PBLA model perform better than those taught using lecture method. This also agreed with the findings of Bas (2011) who carried out a study to investigate the effect of project-based learning on student's academic achievement and attitudes towards English lessons. The results of the study showed that PBLA was very effective in yielding positive development of the student's academic achievement levels. Findings concerning the interaction effect of the independent variable and gender on critical thinking skills shows that there is no significant interaction effect of PBLA and gender on students' achievement. Hence, students' improvement on achievement is solely attributed to the effect of the instructional method used.

In addition, it was also observed that a statistically significant difference occurred between male and female secondary school Biology students' mean critical thinking scores taught ecology with project-based learning method. The result revealed that the

main scores of male and female students differed significantly. The mean score of the male students is higher than the mean score of the female student. It means that the male students were better in critical thinking than their female counterpart. This finding agrees with Haris (2013) who investigated critical thinking skills among ninth standard students in relation to gender, intelligence and study habits in mathematic. The result shows that the male students tend to do better in critical thinking than the female students.

This concurs with the study of Ibrahim (2015) who investigated the impact of 5E teaching cycle on attitude, retention and performance in genetics among pre-NCE Biology students with varied abilities. The study revealed that male and female in all ability groups exposed to 5E teaching cycle performed equally well and had also no difference in their performance and retention abilities. Also, in support of the findings of Mankilik, and Dawal, (2015) who investigated the effect of mastery learning approach (MLA) on the performance of boys and girls in public primary schools in basic science and technology. The findings revealed that there was no significant difference between boys' and girls' performance both of them improved equally in mastery learning approach. This implies that project-based learning is gender friendly and could bridge the gap between the performance between male and female students in biology. This also addresses the issue of equity and inclusiveness.

4.6 Major Findings of the Study

1. PBLA was more effective in enhancing secondary school students critical thinking skills than the lecture method.
2. The findings from the qualitative data support the quantitative findings on critical thinking skills. It reveals that PBLA promotes cognitive processes such as inference, analysis, interpretation and evaluation.

3. The findings reveled that male student performed better in their achievement scores that the female counterpart.
4. The findings shows that there is no interaction effect between the instructional strategy and gender on student's ability in critical thinking skills.
5. The findings revealed that PBLA positively enhances the student's achievement in ecology than the lecture method.
6. The qualitative findings shows that student have deeper knowledge in ecology when they are engaged with learning activities and learning interactions.
7. The findings also shows that there is no interaction effect between the instructional strategy and gender on student's achievement in ecology.
8. The findings reveled that male student are better in critical thinking skills the female counterpart.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the findings from the analysis of the data collected for this study, the researcher concludes that PBLA used for teaching and learning of science provides a means for solving scientific problems, which makes the student to be accountable for their own knowledge. PBLA helps to develop students' process skills, thinking abilities and also a positive attitude towards learning of science. Moreover, the use of PBLA for learning science creates an opportunity for students to identify their strengths and weaknesses throughout the learning process. It is believed that PBLA is a student-centred learning, which prepares learners to relate scientific concepts to real life situations and that it can be adopted for the teaching and learning of science. The use of PBLA as a teaching and learning strategy can improve students' performance in physical science if relevant factors such as teaching aids, large class size, subject teaching qualification, teaching experience can be addressed to and it will impact on learner achievement. It can be concluded that PBL as a student-centered approach is effective in the teaching and learning of biology to improve students' critical thinking skills and achievement.

5.2 Recommendations

Based on the findings of this study, the following recommendations were given:

1. Teachers should use project-based learning to improve the level of critical thinking skills of the students and improve learning process.
2. Teachers can also try project-based learning with other secondary school subjects to enhance the teaching-learning process.
3. The school administration should encourage using project-based learning to teachers in their various institution.

4. The school administration should Provide seminars and workshops on project-based learning for teachers to re-equip them further with the technique and discover more about it.
5. Conduct further studies to validate the data gathered in this study and to advance the use of project- based learning in the teaching-learning process.

5.3 Suggestion for Further Studies

The following suggestion was made for further studies in these areas:

1. While this study focused on enhancing students critical thinking and students' achievement in ecology a similar study can be conducted on retention, and perspective of students towards project-based learning.
2. This study was undertaken in Minna metropolis in Niger state. Similar study can be conducted in another local government area, state or geopolitical zone of the country.

5.4 Contribution to Knowledge

5.4.1 Theoretical contribution

The most significant contribution of the current study is proving a comprehensive understanding of students learning process in project-based. As previous literature has focused mainly on students' achievement and cognitive presence during the discussion on given questions that are clear and well-structured with guidelines and examples (e.g bas 2011, Retnaningshi and Nugrahaningsih 2019, Anteplioglu 2019, Flignona *et al.* 2016, Githae 2015) mainly investigates students' problem solving through the acquisition and application of existing knowledge. This study, however, not only focuses on problem solving but also, that which is important for all secondary students on the construction of new information, through critical thinking and creation of project artefacts.

5.4.2 Methodological contribution

Accordingly, this study also improves the instrument for the analysis. Previous researches focus mainly on the quantitative methods of collecting data for example (Bas 2011, Kizakapan and Bektas 2018, Retnaningshi and Nugrahaningsih 2019, Anteplioglu 2019, flignona and shebaba 2016, Githae 2015). In this present study, both quantitative and qualitative data was collected and was used to analyses the result. Since not many researchers have combined both quantitative and qualitative data in this area before, the research framework such as statement of the problem, objective, research questions and research hypotheses used in this study could be used by future researchers who would want to replicate this study. The instrument (questionnaire and interview guide) used in this research could be used for future research in the same area.

5.4.3 Practical contribution

This study has help students to participate actively in the classroom and promote meaningful and long-lasting learning of student on the topic. It has also help student to transfer their learning to daily life in science and also contributes to students' academic achievement by improving student's higher order thinking skills such as critical thinking, planning problem solving and creativity.

The has also given Biology teachers the opportunity to teach Ecology using PBLA as an instructional approach. The use of PBLA has also help teachers to improve the teaching and learning of ecology and also see the need to develop new and effective methods of teaching biology effectively.

The findings from this research will draw the attention of the curriculum planners/developers and designers to design programs and syllabus that will emphasize the effective use of project-based learning approach in biology.

The findings from this study will also benefits examination bodies like West African Examination Council (WAEC) and National Examination Council (NECO) to help them include critical thinking questions and problem-solving questions in their practical works in biology.

The Government will also benefit from this study as it will offer a more solid base for Nigerian students and also provide such students with more options in Science and Technology which is the hallmark of civilization.

The school administration will benefit from this of the study. This is because less effort will be needed to engage the students in learning biology in a manner that will help students produce better result and this is obviously the expectation of the school for the students to excel academically.

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APPENDICIES

APPENDIX A
PROJECT-BASED LEARNING APPROACH WORKSHEET

The worksheet below is a project-based learning approach work sheet, fill in the blank spaces provided appropriately.
Name of student ……
Class of student…… Date……
The problem environment
Here the teacher introduces the problem. In a particular type of habitat, hybrid specie of Tilapia with red and black color is threatened with extinction and will no longer exist in the habitat. As a group you are been hired by an aquarist to create a model habitat showing these animals so that it can be used to educate generations to come about its history and existence

Phase 1: Introduction

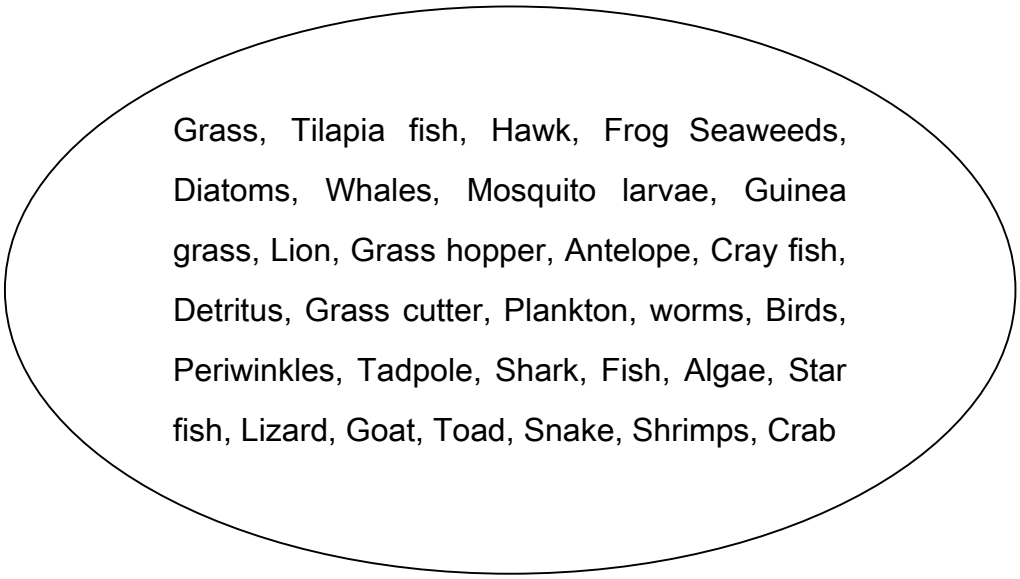
What do you know about the problem	What do you need to know about the problem	How do I advance with the problem

Phase 2: Problem Identification

Questions	Students Response
1. Define/what is the problem	
2. why does the problem exist	
3. what is the important of solving the problem	
4. Converge as a group and share your ideas. write the idea of your group down.	

Phase 3: Investigating the problem

Questions Students Response



Activity 1 From the above list of organism, produce

i. A food chain in terrestrial habitat

ii. A food chain in an aquatic habitat

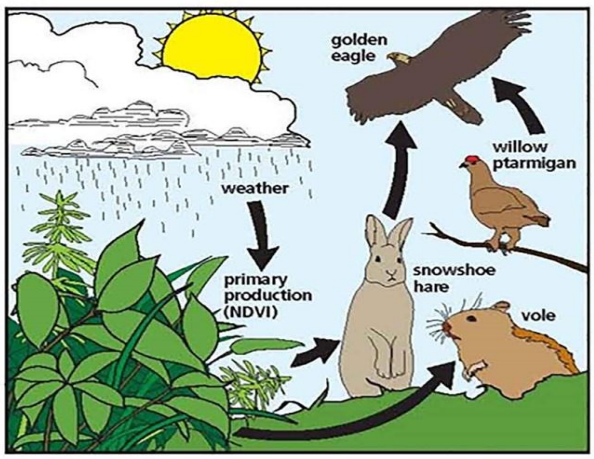
iii. A food web

iv. What do you understand by a food chain

v. What do you understand b a food web

vi. In your words differentiate between a food chain and a food web.

Figure II



Activity 2 From the figure II above, identify

the organism that are

i. Producer

ii. primary consumer

iii. Secondary consumer

iv. Tertiary Consumer

Activity 3 From figure II above, provide answers to the following questions.

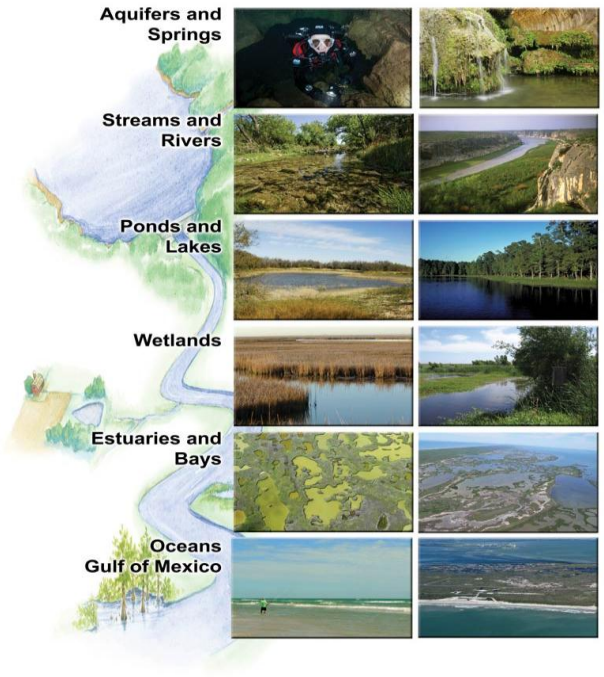
i. How do the organisms interact with one another and the environment?

ii. What would happen if hare is removed?

iii. Looking at figure II, what do you understand by ecosystem?

iv. What is the living (biotic) and non living (abiotic) factors that affect the ecosystem?

Figure III



Activity 4 From figure III above, answer the following questions

i. From the above examples of aquatic habitat, group the habitats into the 3 types of aquatic habitats.
ii. Differentiates between the 3 types of aquatic habitats.
iii. Mention at least 3 examples each of organisms found in the types of aquatic habitats.

Phase 4: Ascertain possible solutions

Questions	Students Response
1. In summary give a clear description of your intensions.	
2. Give a brief proposal on how to solve the problem.	

Phase 5: Design the project

Questions	Students Response
1. Produce a schematic, clear and detail diagram of project design based on the established requirement. 2. Explain your design.	

Phase 6: Presentation of the project

Questions	Students Response
1. Outline the topic and the problem as well as how the group worked together to establish their plan and state the steps employed. 2. In groups present your design to other members of the class, pictures or diagrams is encouraged.	

Phase 7: Evaluation

Questions	Students Response
1. Briefly explain the problem you worked. 2. Does the solution meet the goals of the problem as stated in phase 2? 3. Summaries your projects and challenges faced why carrying out the projects.	If yes, state your reason If no, state your reason

APPENDIX B
PROJECT-BASED LEARNING INSTRUMENTS

In project-based learning the instructional material is usually open ended and well-structured which requires the knowledge of ecosystem before the students can be able to find solutions to solve problems.

Class…….. Subject…….
Topic……. Date……..

Phase 1 — 1st Lesson

Introduction — Contents

In this phase the teacher ask the student, if a particular specie of Rabbit is going into extinction, and that particular Rabbit is needed in the zoo for tourism, what do you need to do to make such specie available for tourism after it extinction.

Instruction

1. Determined the problem, and write the research process by determining what you already know, what you need to know and where you might find the information to help you get an in-depth understanding of the problem. (use the worksheet as a guide to write your ideas).

Phase 2

Problem Identification — Contents

In a particular type of habitat, hybrid specie of Tilapia with red and black color is threatened with extinction and will no longer exist in the habitat. As a group you are been hired by an aquarist to create a model habitat showing these animals so that it can be used to educate generations to come about its history and existence.

Instructions

1. Students work individually by analysis the problem and to get an in-depth understanding of the problem.

2. Students are to meet as a group to brainstorm on what they know about the problem and determine possible solutions

(use the worksheet as a guide to write down your idea).

Phase 3

Investigating the problem

Contents

In this phase the, students work collaboratively and focus on the problem itself and not the potential solutions. The students work collaboratively with their peers to not only determine what they already know but also what they need to know about the problem (such as causes and effect of the problem to the real world).

Phase 4

Ascertain possible solutions

Contents

Instructions

1. From the findings and the ideas that have been brainstorm and discussed from phase 3. As a group, write down your ideas on the possible solution to solve the problem on the comparison table of possible solution.

Irrelevant solutions	Relevant solutions	Relevant solution selected	Most suitable solution for the problem

2. Give a brief description on the solution to the problem and the benefits of the solution to the community now and in the future.

3. What might be damaging or harmful about the solution now or in the future?

4. What might be the limitation of the solution?

Phase 5

Design the project

Contents

In this phase students work collaboratively to design the projects.

Instruction

1. Draw a schematic, clear and detailed sketch of your design-based on the requirement established. (This should be done on the work sheet)

2. In each group, convert your sketch into model.

Phase 6

Presentation of the project

Contents.

In this phase, students will present their project and explain the entire process.

Instruction

1. Prepare a cardboard presentation.

2. Briefly describe the problem you worked to solve.

3. Explain the importance of this problem and how it connects to or affect the real world.

4. What were the unexpected challenges faced?

Phase 7

Evaluation

Contents

Instructions

1. Dose the design meet the goals of the problem highlighted I phase 2?

If yes, state with reasons

If no, state with reasons

2. Propose how you can enhance a better version of the design.

APPENDIX C

BIOLOGY CRITICAL THINKING SKILL TEST INSTRUMENT (BCTST)

TITLE: Enhancing Secondary School Students Critical Thinking Skills and Ecological Achievement using Project-based Learning Approach in Minna, Niger State.

Dear Students,

This critical thinking test instrument is prepared specifically for the purpose of measuring student's critical thinking ability. All the information provided will be used for the purpose of generating data for the research study and will be treated with utmost confidentiality.

The instrument consists of two sections, section A and section B respectively. Section A requires the bio-data of the students while section B is the critical thinking skill test which is further divided into 4 sub skills.

SECTION A: BIO-DATA

STUDENTS NAME:
SCHOOL:
CLASS:
GENDER:
AGE:
DATE:

SECTION B

Instructions: Carefully study the example provided below read each question carefully and circle the correct answers to the questions.

Sub-Skill Inference

Inference is one's ability to draw logically valid or justified conclusion from observed facts. In this section, choose the correct option or options that can be drawn as conclusion from the statement made. For example,

Statement: Every year malaria gets rampant after an increased rainfall. Course of action is?

(i) Pesticide should be properly sprayed on a regular basis.
(ii) People should be supplied with mosquito nets ad mosquito coils free by the government.
(iii) Increase in rainfall result to the spread of malaria.

(a) only I and ii follows (b) only ii and iii follows (d) only iii follows (d) only ii follows (e) either i, ii and iii follows.

From the statement, the problem is malaria and we know that the cause of malaria is increase in rainfall. Hence, the correct option is d

Exercise

1. Statement: Faith lives in the north and observed that plant with thick leaves requires little water.
   (i) All plants with thick leave require little water.
   (ii) Faiths plants may be grown in places where water is not in abundance.
   (iii) All plants with thin leaves require large amount of water.

   (a) only i and ii follows (b) only ii and iii follows (c) only ii follows (d) neither i, ii and iii follows (e) either i, ii or iii follows

2. Statement: An aquarist planted 2 types of sea weed plants in two different zones, one in the Euphotic zone and the other in the Disphotic zone. After 2 weeks the sea weed that was planted in the Euphotic zone was bigger than the one planted in the Disphotic zone.
    (i) Euphotic zone is directly connected to sunlight.
    (ii) Light penetrates in the Disphotic zone at an average level.
    (iii) There is enough sunlight penetration for photosynthesis to occur in the Euphotic zone.

    (a) only i follows (b) only i and iii follows (c) only ii and iii follows (d) only i and ii follows (e) either i, ii or iii i follows.

3. Statement: The temperature of the sea has been low over the years with the population of star fish increasing during this period in the Marine habitat. Reported increase has been rising each year with 2019 being the strongest year of the most populated. In 2020, the population of fish decreases drastically from about 100% to 25%.
    (i) A mysterious illness called sea star wasting syndrome caused the death of starfish.
    (ii) The population decline correlate with rising sea temperatures
    (iii) Chemical pollution caused by mankind has reduced the population of star fish.

    (a) only i and ii follows (b) only ii and iii follows (c) only i and iii follows (d) either i, ii and iii follows (e) only ii follows

4. Statement: An ecosystem is a geographic area where plants and other organism as well as weather and landscape work together to form a bubble of life. hence ecosystem is,
    (i) Ecosystem contains biotic and abiotic factors
    (ii) Ecosystem is controlled by only external factors
    (iii) Ecosystem is a habitat that links together living organism and their relationship with one another.

    (a) only i and ii follows (b) only ii and iii follows (c) only i and iii follows (d) either i, ii and iii follows (e) only ii follows
5. Statement: The principal emphatically state that his teachers will make every possible effort to provide writing materials and project materials for the less privileged students and those on scholarship in biology class
    (i) Except the less privileged students and those on scholarship have got benefits for better A grades
    (ii) No serious effort have been made in the past for the provision of project materials for any group of students
    (iii) All less privileged students and scholarship student have been provided with project materials

    (a) only I and ii follows (b) only ii and iii follows (c) only i and iii follows (d) either i, ii and iii follows (e) Neither I, ii and iii follows

Sub-Skill Analysis

Analysis is the ability to breakdown information into components parts and identify the intended and actual inferential relationship among statements, questions or concept. For example;

Statement: When a solid ball is added to a graduated cylinder with water in it. The water level rises from 20ml to 50ml. What is the volume of the ball?

(a) 20ml
(b) 30ml
(c) 50ml
(d) 70ml

In this example the correct answer is 30ml (a). A students must understand the concept of volume and not get distracted by the spherical nature of the added object. The answer is designed to give the examiner a sense of misunderstanding of volume.

Exercise

1. Statement: The sexually transmitted disease gonorrhea is becoming difficult to treat because the causative bacteria are evolving resistance to antibiotics. for example in Hawaii, between 2000 and 2005 resistance to fluoroquinobneg increased from 1.4% to 9.5%. Scientist attributed this to natural selection. What does natural selection mean in this context?

    (a) The specie of gonorrhea has an inbuilt resistance to fight antibiotics.
    (b) The antibiotic is no longer efficient as it use to be, because of reduced quality in production.
    (c) The antibiotic has changed the genetic structure of the germs allowing them to become antibiotic resistant.
    (d) The germ has increased in number and can't be killed by antibiotic.

2. Statement: Deforestation is the conversion of forested areas to non-forest land use such as arable land, pasture, urban use, logged area or waste land. Generally, the removal or destruction of significant areas of forest cover has resulted in a degraded environment with reduced biodiversity. The water cycle shows the different processes water undergoes. how can deforestation affect water cycle?
    (a) Deforestation does not affect the volume of water that evaporates from ponds lakes and ocean.
    (b) Deforestation reduces the volume of water that evaporates from plants during transpiration, when water precipitates from clouds as rain or snow on to deforested areas, less will be absorbed by plants root and more will run off the surface. This can cause floods & landslides.
    (c) Deforestation increases the effect of global warming and does not affect water cycle
    (d) Deforestation causes the starvation because some trees that provide food for consumption are cut down which in turns affect the water cycle.
3. Statement: The seeds of various plants vary in size from a fraction of millimeter to several centimeters. The most crucial factor controlling the size the of seed a plant produce is?
    (a) Size of the material flower.
    (b) Projected Size of the animal pollination.
    (c) Quantity of the abiotic pollination
    (d) Methods of distribution.
4. Statement: During an otherwise normal pregnancy, a woman begins to experience light headedness and a decline in energy level near the end of the first trimester which of the following is the most likely because of her symptoms?
    (a) Lack of vitamin B due to poor diet.
    (b) Decline of blood ph due to over use of muscles.
    (c) Decrease in blood pressure due to expanding fetal circulation.
    (d) Increase in weight.

5. Statement: As a biology student, should secondary level education be free for all students?
    (a) No, too much education can lead to over qualification and therefore unemployment.
    (b) Yes, having a highly qualified workforce ensures high-level of employee productivity in an organization.
    (c) No research shows that students that are required to pay tuition fees tend to slack off more and learn less during learning.
    (d) Neither of the above.

Sub-skill Interpretation

The sub-skill interpretation is one's ability to comprehend and express the meaning or significance of a wide variety of situation, events, judgment, conventions, beliefs, rules, procedures or criteria. In this question category, a statement is made and you are given a series of option to decide the correct conclusion to the statement. For example:

Statement: Blessing has been an ecologist for four years. She works with a development firm in Lagos and has hopes of being promoted. To be promoted in Blessings firm, employees must have at least five years' experience practicing as an ecologist. Therefore

(a) Blessing cannot be promoted because she doesn't have enough experience.
(b) We cannot know whether Blessing can be promoted or not.
(c) In five years' time, assuming that Blessing has not been promoted, she will be over qualified for her current position.

The correct conclusion to draw from this statement is option (a). The statement indicates that, to be promoted, members of staff must have at least five years' experience practicing as an ecologist. We are told that Blessing only has four years of experience practicing as an ecologist. Therefore, she does not meet the required number of years of experience. With this in mind, we are able to say that she cannot be promoted for this reason the correct answer is option (a).

Exercise

1. Statement: When ice forms across the surface of a lake, it seals up the water from atmospheric oxygen exchange and blocks out much of the light that is necessary for aquatic plants and Phytoplankton to produce oxygen within the lake. This means that:
    (a) Throughout the winter oxygen levels in the lake slowly decline.
    (b) oxygen level is usually at increasing level as the temperature decreases
    (c) Aquatic life does not survive under a frozen lake during winter.
    (d) The temperature at the bottom of the lake decreases and oxygen decreases.

2. Statement: Ecosystem maintains a balance in the environment. It provides fresh air and breath and nutrient through various biogeochemical cycles so that we have access to clean drinking water without any costly methods. It provides food and shelter to a number of living organism it also provides raw materials for different industrial and domestic purposes; however other species are killed for others to survive.
    (a) Ecosystem is a habitat that supports all living organism and provides all requirement to survive.
    (b) Ecosystem is not Conducive for all types of living organisms to inhabit there.
    (c) There are limited biotic and abiotic components that make up the ecosystem.
    (d) Ecosystem only provides habitat for living organism to survive and does not provide the necessary requirement for survival.

3. Statement: An ecosystem is said to be complete if it possesses all the biological and physical components vital for the survival of fishes hence,

(a) An aquarium is a complete ecosystem that has both biotic and abiotic components.
(b) A pond is not a complete ecosystem since it has a still movement of water.
(c) Both ponds and lake are complete ecosystem since it has both biotic and abiotic components present in it.
(d) Neither Pond nor lake is a complete ecosystem.

4. Statement: Four different seeds were planted in the ocean, no one was able to germinate and grow. This experiment lack of photosynthesis shows that oceans are the least productive.

(a) This is because of the type of seed planted in the oceans.
(b) This is because of too much sunlight penetration which affects the growth of plant.
(c) This is because vegetation relies on photosynthesis for energy, sunlight can't penetrate the ocean depths so plants can't grow in deeper waters.
(d) This is because of lack of biotic factors in the water.

5. Statement: Mitochondria are observed in plants cells that contain chloroplast. Why do you find mitochondria in photosynthetic tissues?

(a) Mitochondria are required to break down sugars and other materials
(b) Mitochondria are not needed but are an evolutionary relic,
(c) Mitochondria and chloroplast work together to use light energy to make sugars.
(d) Mitochondria participate in the Calvin cycle night independent reactions of photosynthesis.

Sub-Skill Evaluation

Evaluation is one's ability to assess the credibility of a statement, or sources of information and the claims they make. Evaluation is used to make judgment from the question. Each questions presents a situation and ask you to make a judgment regarding that particular circumstance. Chose an answer based on the given information. For example:

Should companies reduce the numbers of employee's working to decrease expenses and maximize profits?

(a) Yes, reducing the numbers of employee will protect the company from bankruptcy in hard economic time.
(b) Yes, companies have no obligation to employ more people than it can handle.
(c) No, downsizing leads to demoralization of the workforce and causes a drop in employee productivity.

In this example, the correct answer is (b) this is because it addresses the initial statement, providing a clear disadvantage of the statement making the best option.

Exercise

1. Stephanie is a busy zoo aquarist and need a skilled and reliable aquarist to keep things running smoothly. The last two people she hired were recommended by top aquarist in the area, but they each lasted less than one month. She is now in desperate need of an aquarist who at least has a five-year working experience and can completely handle the specific challenges of her practice. Which of the following candidates should Stephanie consider most seriously?

(a) Hajara has been a zoologist for fifteen years and her current employer who is about to retire says she is the best in the business.
(b) Fatima recently graduated at the top of her class from one of the best aquarist programs in the state prior to becoming an aquarist. Fatima spent two years working in a zoo aquarium.
(c) Victoria has worked as an aquarist for five years in a public aquarium center. She is very interested in securing a position in a private aquarium center.

2. The school principal has received complaints from parents about bullying in the school yard during recess. He wants to investigate and end this situation as soon as possible so he asked the recess aides to watch closely. Which situation should the recess aides report to the principal?

(a) A girl is sitting glumly on a bench reading a book and not interacting with her peers.
(b) Four girls are surrounding another girl and seem to have possession of her back pack.
(c) The boys are playing a one game of basketball and are arguing over the last basket scored.

3. Natural breed cat fish are organic in nature. Organic food has more nutritional value and taste better. This means that?

(a) An artificial breed of cat fish can be prepared.
(b) People do not mind paying more for pure and natural cat fish
(c) Natural breed cat fish is the best when it comes to nutrient and taste.

4. In a habitat where there is different type of plants such as sea weeds, algae, e.g sargassum, sesuvium and planktons. This type of habitat is said to be?

(a) An aquatic habitat called fresh water habitat.
(b) A terrestrial habitat called marine habitat.
(c) An aquatic habitat called marine habitat.

5. Rabbits are important grazers maintaining some important grass land habitats if another catastrophe were to reduce rabbit populations, what would happen?

(a) The grass would be invaded by trees and shrubs.
(b) Important grass land butterflies would be lost.
(c) The quantity of grass will reduce since the population of rabbits will be reduced.
(d) There would be more grass for the surviving rabbits.

APPENDIX D

ECOLOGY ACHIEVEMENT TEST INSTRUMENT (EAT)

Dear students,

The instrument, ecological achievement test for senior secondary school students is specifically for the purpose of measuring student's achievements in the concept of ecology in biology. The result generated will be treated confidentially and will be used for this research work.

The instrument consist of two sections, section A and Section B. Section A requires the bio-data of the students while section B is the Ecology Achievement Test (EAT) questions. Please carefully read through and provide the necessary answers to the questions.

Thanks for your co-operation.

SECTION A: BIO-DATA
STUDENTS NAME:
SCHOOL:
CLASS:
GENDER:
AGE:
DATE:

SECTION B: ANSWER ALL QUESTIONS.

INSTRUCTIONS: Carefully read the following questions and choose the correct answers from option A-D.

1. A peacock eats snakes which eats frog then eat hoppers which in turn thrive on leaf of plants. The peacock is?
   (A) Primary consumer
   (B) Secondary consumer
   (C) Decomposer
   (D) Apex of the food of the pyramid

2. A food chain shows relationship between organisms by the food they eat, in this statement a food chain can e described as?
   (A) Group of organisms which eat the same food
   (B) Animals eating animals eating
   (C) Series of plant/animals which are interrelated in the form of organisms being eaten as food by others
   (D) None of these

3. An ecosystem is a geographic area where plants and other organisms as well as weather and landscape work together to form a buddle of life. Hence ecosystem is?
   (A) A specie along with environment
   (B) Plant found in water
   (C) Plant found on land
   (D) Group of plants & animal species along with the environment.

4. An animal secretes concentrated urine, and ability to store water in the body. The organism is likely to be inhabitant of?
   (A) Mountains
   (B) Saline water
   (C) Desert
   (D) All of the above

5. What would most likely happen if an ecosystem no longer received sunlight?

(A) The numbers of herbivores would increase
(B) The numbers of plants would increase
(C) All organisms would adapt
(D) All living Organism would eventually die

6. The habitats for marine organism are based on which of the following chemical and physical properties?
(A) The salt content of the water
(B) The ocean current in the river
(C) The temperature of the water
(D) The Ocean currents in that area

7. Which of these factors increases the size of a population?
(A) Birth rate
(B) Emigration
(C) Death rate
(D) Carrying capacity

8. A change in which of these factor is least likely to affect the distribution moth?
(A) Temperature
(B) Composition of gases in the atmosphere
(C) Availability of water
(D) Group of plants and animal species along with the environment found on land

9. A certain plants need moisture carbon oxide, oxygen, light and minerals to survive. The Scenario shows that a living organism depends on
(A) Biotic factors
(B) Symbiotic relationship
(C) Abiotic factors
(D) Carnivore-herbivore relationships.

10. Primary consumers are organisms that feed on primary producers. Primary consumer are?
(A) Green Plants
(B) Herbivores animals
(C) Carnivorous animals
(D) None of the above

11. Vegetation of a geographic region with low rain fall, high temperature loose and sandy soil is of the type called?
(A) Ever green tropical forest
(B) Grassland
(C) Scrub forest
(D) Xerophotic

12. If all green plants of the earth are destroyed,
(A) All plants would die
(B) Only herbivores would die
(C) All animals would die ultimately
(D) Nothing would happen to animals.

13. Primary consumer are organisms that feeds on primary producers. Primary producers are?
(A) Green plants
(B) Herbivores animals
(C) Carnivorous
(D) None of the above

14. The utmost element in a food chain is one of the following

(A) Photosynthesis
(B) Respiration
(C) Nitrogen fixation
(D) Decay

15. Which of the following is among the world's most productive ecosystem in terms of biomass production?

(A)Pond ecosystem
(B) Lake ecosystem
(C) Brackish ecosystem
(D) River ecosystem

16. Which of the following are adaptations for avoiding unfavorable conditions?

(A) Migration
(B) Dormancy
(C) Body temperature regulation
(D) Aquatic habitat

17. Sunlight is the utmost source of energy for green plants. Producers in any grazing food chain

(A) Feeds on herbivores
(B) Feeds on carnivorous
(C) Clean the atmosphere
(D) Capture solar energy

18. When a big fish eats a small fish which eats water fleas supported by phytoplankton. Water fleas are?

(A) Producers
(B) Primary consumers
(C) Secondary consumers
(D) Top consumers

19. During a long period when there is no rainfall, a mountain lion may temporary leave its usual hunting territory to drink from a farm pond. To what is this behavior attributed to?

(A) It's need to find different foods to eat
(B) The change in an abiotic factor in its environment
(C) it's need to find a new habitat
(D) The change in a biotic factor in its environment.

20. Rabbits are important grazers, maintaining some important grassland habitats if another catastrophe were to reduce rabbit populations, what would happen?

(A) The grass would be invaded by trees and shrubs
(B) Important grassland butterflies would be lost
(C) The quantity of grass will reduce since the population of rabbits will be reduced
(D) There would be more grass for the surviving rabbits

21. Frogs are animals with high fecundity. Based on this information, Frogs also have one of the following characteristics

(A) High energy budget
(B) Extensive energy storage for off spring
(C) Small numbers of off spring
(D) Little or no parental care

22. Certain part of the earth is covered with water, while in some part of water is near the surface of the soil. This can best describe

(A) Desert
(B) Ocean
(C) Estuary
(D) Wetland

23. Regulation of population in an ecosystem signifies
(A) Functional ecosystem
(B) Dysfunctional ecosystem
(C) Complex ecosystem
(D) Linear ecosystem

24. Which of the following is not true about a food chain?
(A) Passage of food from one tropic level to the next higher one
(B) Passage of energy from one tropic level to the next higher one
(C) Dissipation of energy as successive tropic level
(D) Delicately balances the inter relation among organisms

25. A pond ecosystem in an open field begins to be shaded by the growth of trees around its perimeter. Predict changes in this pond after the tree grow large enough to completely shade the pond.
(A) The population size of all organisms will increase in response to lower energy flowing into the pond.
(B) The population density of all organisms will increase in response to lower temperature in the pond.
(C) The population distribution of large organism will shift from clumped to random in response to lower energy flowing into the pond.
(D) The population distributions of small organisms will shift from uniform to clumped in response to lower temperature in the pond.

26. Predict how human population change in the next 50 years is likely to affect marine ecosystem.
(A) Human will decrease their own carrying capacities which will also decrease the carrying capacities of marine ecosystem.
(B) Decreased fishing can be expected which will lead to rebounds in fish populations and healthier marine ecosystem

(C) Increase in green house gas emissions are likely to increase in ocean temperatures that triggers shifts in marine population.

(D) Biodiversity of marine ecosystem will increase as humans use engineering to increase food production in the oceans.

27. An ecologist is planning to measure both the size and density of a population. Identify the experimental methods that can best provide these data
(A) Mark and recapture
(B) Quadrant
(C) Life table
(D) Mark and release

28. Albatrosses are birds that can live to age 60 and older. They usually do not start breeding until they reach age 8 or 9, which is relatively late compared to other birds specie based on this information, explain conditions that might be a risk to the survival of albatrosses.
(A) Increased chances of human dying before reproducing.
(B) Decreased chances of mating between individuals.

(C) Decreased life span of individual
(D) Increased chances of offspring dying.

29. Which of the following is among the world's most productive ecosystem in terms of biomass production?

(A)Pond ecosystem
(B) Lake ecosystem
(C) Brackish ecosystem
(D) River ecosystem

30. The habitats for marine organism are based on which of the following chemical and physical properties?

(A) The salt content of the water
(B) The ocean current in the river
(C) The temperature of the water
(D) The Ocean currents in that area

APPENDIX E

PROJECT-BASED LEARNING INTERVIEW QUESTION PROTOCOL

The instrument is for senior secondary school students who participated in the project-based learning process. It is specifically for the purpose of exploring students experience during the learning process. The response generated will be treated confidentially and will be used for this research work.

The instrument consists of two sections, section A and Section B. Section A requires the bio-data of the students while section B is the interview questions.

Thanks for your co-operation.

SECTION A: BIO-DATA

STUDENTS NAME:

SCHOOL:

CLASS:

GENDER:

AGE:

SECTION B: INTERVIEW QUESTION

1. What is your experience learning with PBLA?
2. Did you enjoy the teaching and learning process? If yes why? If no why?
3. Which part of the activity did you enjoy the most?
4. What did you like least about working with this project?
5. How did you learn ecology using project-based learning approach?
6. Given a chance, what is one change you will like to see in the teaching process?
7. Are you satisfied using project-based learning approach?
8. What new skills have you learnt in the cause of your experience?
9. What was the role of the teacher during PBLA?

APPENDIX F

RELIABILITY OUTPUT FOR INFERENCE SUB-SKILLS

Reliability
Scale: ALL VARIABLE

Case Processing Summary

		N	%
Cases	Valid	20	95.2
	Excluded[a]	1	4.8
	Total	21	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.974	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.952[a]	.883	.981	38.972	19	19	.000
Average Measures	.975	.938	.990	38.972	19	19	.000

Two-way random effects model where both people effects and measures effects are random.
a. The estimator is the same, whether the interaction effect is present or not.
b. Type A intraclass correlation coefficients using an absolute agreement definition.
c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

APPENDIX G

RELIABILITY OUTPUT FOR ANALYSIS SUB-SKILLS

Reliability
Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	20	100.0
	Excluded[a]	0	.0
	Total	20	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.741	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.584[a]	.214	.810	3.857	19	19	.003
Average Measures	.737[c]	.352	.895	3.857	19	19	.003

Two-way mixed effects model where people effects are random and measures effects are fixed.
a. The estimator is the same, whether the interaction effect is present or not.
b. Type A intraclass correlation coefficients using an absolute agreement definition.
c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

APPENDIX H

RELIABILITY OUTPUT FOR INTERPRETATION SUB-SKILLS

Reliability
Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	20	95.2
	Excluded[a]	1	4.8
	Total	21	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.834	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.721[a]	.420	.879	6.026	19	19	.000
Average Measures	.838	.592	.936	6.026	19	19	.000

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

APPENDIX I

RELIABILITY OUTPUT FOR EVALUATION SUB-SKILLS

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	20	95.2
	Excluded[a]	1	4.8
	Total	21	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.721	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.547[a]	.168	.789	3.585	19	19	.004
Average Measures	.707	.288	.882	3.585	19	19	.004

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

APPENDIX J

RELIABILITY OUTPUT FOR EAT

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	20	100.0
	Excluded[a]	0	.0
	Total	20	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.834	2

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.721[a]	.420	.879	6.026	19	19	.000
Average Measures	.838	.592	.936	6.026	19	19	.000

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.