EFFECTS OF PROBLEM AND DISCOVERY-BASED INSTRUCTIONAL STRATEGIES ON STUDENTS' ACADEMIC ACHIEVEMENT IN CHEMISTRY IN DELTA CENTRAL SENATORIAL DISTRICT

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DELTA STATE UNIVERSITY, ABRAKA

JANUARY, 2018

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CERTIFICATION

This is to certify that I am responsible for this research work, that the original work submitted is mine except as specified in the references and acknowledgements; neither the dissertation, nor the original work contained here has been submitted to this University or any other institution for the award of a degree.

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APPROVAL PAGE

This dissertation has been approved for the award of Masters Degree in the Department of Science Education, Faculty of Education, Delta State University, Abraka.

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DEDICATION

This research work is dedicated to my lovely parents, Mr. and Mrs. Help E. Obonofiemro.

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ABSTRACT

This study investigated the effects of problem-based and discovery-based instructional strategies on students' academic achievement in chemistry in Delta Central Senatorial District of Delta State. Eight research questions and eight hypotheses guided the study. The quasi-experimental design was used, specifically the non-equivalent control group pre-test posttest design. A sample of 316 Senior Secondary School two (SS II) Chemistry students selected using stratified sampling technique from six secondary schools in Delta Central Senatorial District were used for the study. The instrument for data collection was Chemistry Achievement Test (CAT) validated by one chemistry science educator, an expert in measurement and evaluation and an experienced chemistry teacher. The reliability of the instrument was established using Kudder-Richardson formula 21 which yielded coefficient of internal consistency of 0.83. Data were collected by administering the CAT as pretest and posttest. The data obtained were analyzed using mean, standard deviation, t-test, Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA). The results showed that there was a significant difference between the mean achievement scores in chemistry of students in the problem-based instructional strategy, discovery-based instructional strategy and lecture method with students in the problem-based instructional strategy group scoring the highest marks, followed by students in discovery-based instructional strategy and lecture method respectively; there was no significant difference between the mean achievement scores of students taught chemistry using problem-based and discovery-based instructional strategies in urban and rural areas; there was a significant difference between the mean achievement scores of male and female students taught chemistry using problem-based instructional strategy in favour of male. The results also showed that there was a significant interaction effect between teaching methods and genders on achievement scores in CAT. It was recommended that chemistry teachers should adopt problem-based and discovery-based instructional strategies in the teaching of chemistry concepts. Special training on how to use problem-based and discovery-based instructional strategies in teaching should be organized for chemistry teachers by the government to help them effectively implement problem-based and discovery-based instructional strategies in classroom teaching.

CHAPTER ONE

INTRODUCTION

Background to the Study

Chemistry is a branch of science that studies the properties, composition, reactions and uses of matter. Chemistry as a subject taught in secondary schools and universities is divided into many branches which includes; Biochemistry, Organic chemistry, Inorganic chemistry, Physical chemistry, Medical chemistry, Nuclear Chemistry, Environmental chemistry etc. Chemistry play a major role in building the scientific base of a country in the sense that it's a prerequisite for higher learning of science based discipline such as Engineering, Medicine, Industrial and Pure Chemistry, Microbiology, Anatomy, Pharmacology, Pharmacy etc. The performances of Nigerian students in chemistry at the secondary school level remain a dismal failure despite the increasing importance of chemistry (WAEC Chief Examiner report, 2015).

Students' performance in chemistry has continued to decline irrespective of the efforts of government in provision of infrastructural facilities, instructional materials, conducive learning environment, in-service training to teachers and regular supervision of teachers. The desire to know the causes of poor performance in chemistry has been the focus of researchers for some time now. It has been observed that poor performances in the sciences in general and chemistry in particular are caused by poor quality of science teachers, overcrowded classrooms, lack of suitable and adequate science equipment, large class size, heterogeneous classroom in terms of ability level, ill equipped laboratories, overloaded chemistry syllabus and poor teaching methods (Kareem, 2003; Onwirhiren, 2005; Armed, 2008). These factors encourage chemistry teachers to resort to only lecture instructional strategies most of the time. It is a well known fact that the quality of education depends on the teachers and so the method they adopt in teaching matters a lot.

The educational system of nearly every nation of the world usually places some level of emphasis on the strategy or method of instruction. This is because the varied methods of instruction are unique in their own respects and are suitable under certain conditions. These conditions could be such as related to the learner, the teacher, the school, style of administration, the availability of instructional materials, availability or lack of fund, instructor's mastery of the method, time duration of the lesson, the subject or lesson content and so on (Nwanze, 2016). The various conditions aforementioned therefore, determine the choice of method of instruction. Some of the methods however are suitable for science instructions whereas some hold lesser benefits for science learning. Hence, a yardstick to determine the effectiveness of an instructional method is dependent on the extent to which the instructional method promotes the attainment of instructional objectives.

The various methods of instruction are normally anchored on some theories of learning. Notable among these theories in recent times is the theory of constructivism. The constructivists hold the view that learning should primarily involve the learner and that it facilitates the learners' ability to conceptualize learning contents (Nwanze, 2016). The idea proceeds from the notion that knowledge is a human construct and is culturally and socially constructed. Thus, meaningful learning takes place when the learners are socially involved (Vygotsky, 1978). Teaching methods that enable students' subject matter conceptualization and student-student as well as teacher-student interactions could enhance achievement as students can learn from each other's concepts that they could not learn independently. Such learning approaches are better suited for teaching and learning science concepts including Chemistry. Problem-based and discovery-based instructional strategies are among these strategies.

Problem-based learning as a strategy for learning consists of carefully selected and designed problems that demand from the learner acquisition of critical knowledge, problem solving proficiency, self directed learning strategies and team participation skills (Maloney, 2004). It reduces teacher's centred instruction where learners are seen as active listeners and passively involved in classroom activities as in the case of lecture method. Problem- based learning is an example of constructivist learning strategy which poses significant contextualized real world situations and provides resources, guidance, and instruction to learning as they develop content knowledge and problem solving skills (Yager, 1991).

The first task for the teacher in problem based learning is to guide the student to identify the problems and help them to link with previous knowledge (Anyafulude, 2014). The student in a small group discuss the problem cooperatively among themselves in a small group, explain what they know, pose research questions, generate hypotheses, develop initial plans and organize their knowledge, attempt to solve the problems with several modifications, derive learning goals and organize further work (Afolabi & Akinbobola, 2012). Finally, the results are presented to larger groups through the guidance of the teacher, instructor or facilitator and the students are allowed to reflect on the learning that has taken place (Afolabi & Akinbobola, 2012). Problem-based learning is a form of inquiring-based learning which explains the environment in which learning is driven by a process of inquiry constructed by the students. Research-based evidence has shown that problem-based strategy improves students' learning outcome (Ajai, Imoko & O'kwu, 2013; Ali, Hukamadad, Akhter & Khan, 2010; Anyafulude, 2014; Celik, Onder & Silay, 2011). Problem-based instructional strategy was found by Anyafulude (2014) to have positive effect on students' academic achievement. Anyafulude found that students taught with problem-based instructional strategy achieved better than those taught with the lecture method. Celik, Onder and Silay (2011) reaffirmed the superiority of problem-based strategy over the lecture method in improving students' academic achievement.

Discovery is a way from the unknown to the known by the learners themselves (Bruner, 1966). The active participation of the learner in the learning process is called discovery learning (Bruner, 1968; Kara & Ozgun-Coca, 2004; Kipnis, 2005). In discovery learning, students construct knowledge based on new information and data collected are used by them in an explorative learning environment (De Jong & Van Joolingen, 1998).

Bruner (1961) stated that learning happens by discovering, which prioritizes reflection, thinking, experimenting, and exploring. Discovery instructional approach to education is more closely aligned with constructivist concepts of exploration, discovery and invention (Bok, 2006). Discovery method according to Uwameiyi and Ogunbemeru (2005) is a method of teaching that has the advantages of allowing learners to use process skills to generate content information. Guided discovery method activity engages learners in first hand real world learning. Uwameiyi and Ogunbemeru (2005) stated further that guided discovery method encourages learners to explore the content through the use of concrete experience. Fatokun and Yallams (2007) also describes discovery method as resource-based learning which is an innovation that reverses the usual role of the teacher from that in which he is the main authority and source of all knowledge to that in which he acts simply as a guide to the students to enable them to make use of other source of information. The teacher is no longer the focal point of the classroom, instead the would be instructor is now seen as a "facilitator, mentor, coach or consultant" (Honebein, 2006). The discovery-based strategy is an excellent means of fostering co-operation amongst learners for instance, in group project, members contributes and learn from each other. Research-based evidence has shown that discovery-based strategy improves students' learning outcome. Balim (2009) observed that students taught with discovery-based instructional strategy outperformed their counterpart taught using the lecture method.

Over the years, the predominant method of instruction in schools has been the lecture method (Nwabufor, 2005). By this method, learners were encouraged to master course content through constant repetition of facts and drills (Anyafulude, 2014). The method guarantees the completion of the course outline on time, but incidentally encourages learners to memorize and regurgitate content of learning experiences instead of digesting and assimilating them (Ajaja, 2009). In Nigerian schools, most teachers use the lecture method, which unfortunately provides little or no room for active student participation in the lesson. Perhaps this may account for the poor achievement often recorded in public examinations. This is a pointer that something is wrong with the teaching and learning of the subject. It becomes pertinent that classroom practices should be improved using innovative teaching methods which will involve active participation of the students thereby stimulating learning.

In response to the problem of poor performance in secondary school Chemistry, the WAEC Chief Examiner's report recommended the use of effective teaching method which is in tune with the modern science and technological dispensation as the only remedy to students' poor performance in Chemistry (WAEC Chief Examiner report, 2015). Hence, problem-based and discovery-based learning can be used to enhance students' achievement in Chemistry.

Gender of the student has also been reported as a predicting factor of students' achievement in chemistry. Bosede (2010) asserted that gender of the student influence student academic achievement in some subject areas. Okeke (2008) gave a broad analytical concept which draws out women's role and responsibilities in relation to those of men. According to Okeke (2008), gender refers to those characteristics of males or females which are biologically determined such as possession of penis by males and vagina by females. To Okeke, gender refers to the socially culturally constructed characteristics and roles which are ascribed to males and females in any society. Gender is a major factor that influences career choice and subject interest of students. Okeke (2008) described the males' attributes as bold, aggressive, tactful, economical use of words while the females are fearful, timid, gentle, dull, submissive and talkative. May be that is the reason Umoh (2003) stated that more difficult works are usually reserved for males while the females are considered feminine in a natural setting. Thus in schools, males are more likely to take to difficult subject areas like science (chemistry) while the females take to career that will not conflict with marriage chances, marriage responsibilities and motherhood (Okeke 2008). The reports on gender as a predicting factor of students' achievement in sciences are mixed. While some findings indicated no significant effect of gender on science achievement (Olatoye, 2009; Ajaja, 2013), some researchers reported significant influence of gender on academic achievement with boys having better scores than girls in the study (Akala, 2009; Balogun, 2000).

Location of schools could also affect chemistry achievement. Ezeudu (2003) stated that schools location means urban and rural schools. School location in a particular place differs in relation to other areas (Quirk, 2008). Akpan (2008) indicated that schools in urban areas have electricity, water supply, more teachers more learning facilities and infrastructure. To support this Ezike (2001) stated that urban areas are those with high population density, high variety and beauty while rural areas are those with low population, subsistence mode of life, monotonous and burden. Reports on location as a predicting factor of students' achievement in sciences are mixed. Onah (2011) and Owoeye (2002) indicated that students in the urban areas achieved more than students in the rural areas in science subjects. Specifically Owoeye and Yara (2011) showed in their studies that students in urban locations had better academic achievement than their rural counterpart in chemistry. Yet Ezeudu (2003) and Bosede (2010) showed that location has no effect on students' academic achievement.

In this study however, the researcher seeks to ascertain if the use of problem-based and discovery-based instructional strategies could improve the students' chemistry achievement with gender and school location as moderating variables. Against this background, this study is designed to determine the effects of problem-based and discovery-based instructional strategies on students' academic achievement in chemistry in Delta Central Senatorial District of Delta.

Statement of the Problem

Chemistry is a science subject that contains a lot of difficult concepts that demands a lot from both the teachers and the students for it to be properly learnt. Students' poor performance in WAEC as reported by WAEC Chief Examiner's report (2015) revealed that there is a continuous decline in students' performance in chemistry. This decline may be attributed to the fact that students have resorted to memorization of chemistry concept as a result of their passive involvement in the teaching and learning process due to the lecture method of teaching. It is very obvious that the lecture method of teaching has not truly yielded the required result in terms of students' achievement specifically in chemistry. This calls for the adoption of other teaching methods that could ensure the active involvement of students in the teaching and learning process and also provide the opportunity for students to discover new knowledge on their own with little or no assistance from teachers. Problem-based and discovery-based instructional methods could be alternatives as they ensure students active involvement in the teaching and learning process and also encourage students' discovery of new knowledge on their own.

There have been a lot of comments in books, particularly those written in Europe and America, which confirmed problem-based and discovery-based learning to be effective ways to structure learning activities (Ali, Hukamadad, Akhter & Khan, 2010; Celik, Onder & Silay, 2011). Surprisingly, there is little research effort, particularly in Nigeria, that emphasized the effectiveness of problem-based and discovery-based learning in science and chemistry in particular at senior secondary school level (Anyafulude, 2014). Furthermore, no studies to my knowledge had investigated the effects of problem-based and discovery-based learning and their interaction with gender and location on chemistry achievement among senior secondary school students in Delta Central Senatorial District of Delta State. The problem of this study therefore is, will the use of problem-based and discovery-based instructional strategies enhance higher achievement of students in chemistry? This study investigated the effects of problem-based and discovery-based instructional strategies on students' achievement in chemistry.

Research Questions

The following research questions were raised to guide the study:

1. Is there any difference in the mean achievement scores among students taught chemistry using problem-based, discovery-based and lecture methods?
2. Is there any difference in the mean achievement scores of students taught chemistry using problem-based instructional strategy in urban and rural area?
3. Is there any difference in the mean achievement scores of students taught chemistry using discovery-based instructional strategy in urban and rural area?
4. Is there any difference in the mean achievement scores of male and female students taught chemistry using problem-based instructional strategy?
5. Is there any difference in the mean achievement scores of male and female students taught chemistry using discovery-based instructional strategy?
6. Is there any interaction effect between teaching methods and gender on achievement in chemistry?

7. Is there any interaction effect between teaching methods and school location on achievement in chemistry?
8. Is there any interaction effect among teaching methods, gender and school location on achievement in chemistry?

Hypotheses

1. There is no significant difference in the mean achievement scores among students taught chemistry using problem-based, discovery-based and lecture methods.
2. There is no significant difference in the mean achievement scores between students taught chemistry using problem-based instructional strategy in urban and rural area.
3. There is no significant difference in the mean achievement scores between students taught chemistry using discovery-based instructional strategy in urban and rural area.
4. There is no significant difference between the mean achievement scores of male and female students taught chemistry using problem-based instructional strategy.
5. There is no significant difference between the mean achievement scores of male and female students taught chemistry using discovery-based instructional strategy.
6. There is no significant interaction effect between gender and method on achievement in chemistry.

7. There is no significant interaction effect between method and school location on achievement in chemistry.
8. There is no significant interaction effect among gender, method and school location on achievement in chemistry.

Purpose of the Study

The purpose of this study is to examine the effects of problem-based and discovery-based instructional strategies on secondary school students' academic achievement in chemistry.

Specifically, the study seeks to determine:

1. if there is a difference in the mean achievement scores of students taught chemistry using problem-based, discovery-based and lecture methods with the intention of isolating which one among them will be most effective for teaching chemistry;
2. if there is a difference in the mean achievement scores of students taught chemistry using problem-based instructional strategy in urban and rural area;
3. if there is a difference in the mean achievement scores of students taught chemistry using discovery-based instructional strategy in urban and rural area;
4. If there is a difference in the mean achievement scores of male and female students taught Chemistry using problem-based instructional strategy;
5. if there is a difference in the mean achievement scores of male and female students taught Chemistry using discovery-based instructional strategy;
6. if there is an interaction effect between gender and method on achievement in chemistry;

7. if there is an interaction effect between method and location on achievement in chemistry;
8. if there is an interaction effect among gender, method and school location on achievement in chemistry.

Significance of the Study

The findings of this study may be beneficial to students, teachers, textbook writers, chemistry curriculum designer and future researchers.

The findings of this study might help students appreciate how the interaction among themselves and their teachers affect their academic achievement. It might also provide students with the appropriate steps to follow in discovering new ideas on their own without relying on their teachers.

Teachers of science-related subjects through the findings of the study might be stimulated to adopt the problem-based and discovery-based instructional approach. They might become cognizant of the benefits underlying these approaches and how it can ease the teaching activities while improving students' achievements.

The findings of this study might incite textbook writers to design and arrange subject matter contents in such a way that it could facilitate problem-based and discovery-based learning without requiring extra effort from the teachers and to allocate more time in arranging learning experience to facilitate learning.

The findings of this study might serve as a guide to chemistry curriculum planners for developing teaching strategies for teachers on how to improve students' performance in chemistry by specifically stating the steps involved in a given strategy.

The findings of this study will enrich chemistry literature and might serve as a source of related literature to researchers who are investigating a similar or related topic in their studies.

Scope and Delimitation of the Study

The study is restricted to the effects of problem-based and discovery-based instructional strategies on Senior Secondary two (SS II) students' achievement in chemistry. It further looked at the effects of problem-based and discovery-based strategies on male and female student achievement in chemistry as well as the achievement of students from urban and rural schools in chemistry. The chemistry concepts covered are occurrence and electronic structure of nitrogen, laboratory and industrial preparation of nitrogen, and uses and industrial preparation of ammonia.

The study is delimited to all urban and rural public secondary schools in Delta Central Senatorial District of Delta State.

Limitation of the Study

The limitation of this study is appreciated in two folds:

1. The SS 2 students used for the study were not familiar with the use of problem-based and discovery-based instructional strategies. These approaches may have slowed down learning in the first two weeks of lesson since students are more familiar with the lecture method of teaching. This distortion may have affected their achievement.
2. The timeframe allocated to the chemistry content in the school time table was not sufficient for the effective implementation of problem-based and discovery-

based instructional strategies. This affected the academic achievement of the slow learners.

Operational Definition of Terms

The terms below are defined operationally as used in this study:

Problem-based Instructional Strategy: Problem-based learning is an approach that challenges students to learn through engagement in a real problem. Investigation in the science classroom begins with a problem. Problem solving as a teaching strategy embodies most of the techniques and learning skills science educators consider important when learning science by investigative method.

Discovery-based Instructional Method: This is a teaching strategy that encourage students active participation in classroom learning by answering set of questions posed by the teacher by observing, classifying, measuring, predicting, describing and inferring. Discovery learning takes place in problem-solving situations where the learner draws on his own experience and prior knowledge to discover the truths that are to be learned.

Academic Achievement: This is the level of proficiency attained in academic work or as formally acquired knowledge in chemistry which is often represented by percentage of marks obtained by students in examinations or test.

Gender: This simply refers to male and female secondary school students.

School location: This simply refers to schools located in urban and rural area.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter is organized under the following sub-headings:

- Theoretical Framework
- Concept of Problem-based Instructional Strategy
- Concept of Discovery-based Instructional Strategy
- Concept of Academic Achievement
- Problem-based Instructional Strategy on Students' Academic Achievement
- Empirical Studies on the Effect of Problem-based Instructional Strategy on Students' Academic Achievement
- Empirical Studies on the Effect of Discovery-based Instructional Strategy on Students' Academic Achievement
- Effect of Problem-based and Discovery-based Instructional Strategy on Male and Female Students Academic Achievement
- Effect of Problem-based and Discovery-based Instructional Strategy on Urban and Rural Students Academic Achievement
- Appraisal of Reviewed Literature

Theoretical Framework

The cognitive theories upon which this study is anchored are reviewed below:

Jean Piaget Cognitive Development Theory

The theory of cognitive development was postulated by Piaget in 1962. The theory stated that cognitive development is a progressive reorganization of mental process resulting from biological maturation and environmental experience. According to Piaget, children actively seek out information and adapt it to the knowledge and conceptions of the world that they already have. Thus, children construct their understanding of reality from their own experience. Children organize their knowledge into increasingly complex cognitive structures called schemata.

Children possess many different schemata, and these change as the children develop. In the newborn, the schemata take the form of innate reflexes and reaction patterns, like sucking. As the child grows and gains experience, the schemata shift from motor activities to mental activities called operations. These operations become increasingly complex with age. Piaget suggested that schemata are modified according to the principles of organization and adaptation, which continue to operate throughout the life span. Organization is the predisposition to combine simple physical or psychological structures into more complex systems. Adaptation involves the two complementary processes of assimilation, or fitting new experiences into current cognitive schemata, and accommodation, or adjusting current schemata to fit the new experiences. Most encounters involve both processes.

Assimilation: Assimilation means a process of interpreting actions or events in relation to one's schemas. This refers to a means of fitting reality into one's existing structures of knowledge. The term 'schemas', for Piaget, refers to a well defined sequence of physical and mental actions.

Accommodation: This is the modification of existing schemas to fit reality. The organism is capable of learning when it can modify its schemas. As the organism continues to accommodate, it continues to learn. Piaget believes that cognition develops from age to age and from level to level. According to Piaget, the driving force for cognitive development is equilibration. By equilibration, Piaget means balancing assimilation and accommodation to adapt to the demands of the environment.

Piaget believes that for people to learn, they must assimilate and accommodate. Piaget opined that at each stage of development, people use a distinctive underlying logic or structure of reasoning to guide their thinking. Piaget identified four stages of cognitive development – sensory-motor, pre-operational, concrete operational and formal operational to explain cognitive development from infancy to adolescence. However, we should be concerned with the ‘formal operational stage’. This stage occurs within the adolescence stage. At this stage, the young individual can start to think more abstractly. This stage of cognitive learning is characterized by ability to manipulate abstract as well as concrete objects, ideas, and events. At formal operational stage, the young individual acquires more ability to deal with abstractions and may engage in hypothetical reasoning based on logic. At the adolescence stage, individuals can easily carry out practical experiments and demonstrations. Formal operational stage offers the ability for the individual to use abstract symbols for representational purposes. For instance, the individual, if taught, could understand that H_2O is water and may abstractly understand why it represents water.

Piaget’s theory of intellectual development holds that cognitive development takes place from active interaction of the child with his environment. This means that the basis of learning is the child’s own ability as he interacts with his physical and social environment. Piaget is of the opinion that a child must act on the objects in his environment for him to learn. This means that he should be actively involved not be passive. The active involvement of the child may be in form of direct manipulation, visual observation or through mental or internal transportation or change. Piaget believed that mental activity, which is involved in cognitive organization, is a process of adaptation, which is divided into two opposing but inseparable processes of assimilation and accommodation. Accommodation means to modify self to fit the new materials, while assimilation means to modify the materials to fit the self. The Piagetian theory places the child as the principal agent in the teaching/ learning situation. This being the case, the teacher's job is to provide the individual with situations that encourage experimentation and manipulation of objects and symbols.

The theory has direct implication on the researcher's study: effects of problem-based and discovery-based instructional strategy on students' academic achievement in chemistry. In the first place, the Piagetian theory of intellectual development holds that cognitive development takes place from active interaction of the child with his environment. Problem-based and discovery-based instructional strategies are student-centered, activity oriented- teaching strategy in which the teacher acts as a facilitator of learning, guiding the students through a series of activities and problems, which will enhance achievement by learners.

Secondly, Piaget's theory emphasized active participation of the child in the teaching and learning process which problem solving and discovery method encourages. This is because when students are allowed to discover knowledge on their own, the students may likely understand the subject matter better as they pass from the known to the unknown and in an increasing order of difficulty. A child must master a step before proceeding to the next one and in doing so, the learner is actively involved in the learning process. Moreover, there are a lot of activities which the learner is expected to carry out by himself, making the learner very active in the learning process.

Lev Vygotsky Cognitive Development Theory

Vygotsky (1978) cognitive development theory postulates that social interaction precedes development; consciousness and cognition are the end product of socialization and social behavior. Vygotsky emphasized the impact of cultural and social influences on cognitive development, particularly the interaction of children with other people in cognitive development (Rice & Wilson, 1999). Vygotsky's theory of cognitive development centered on the ideas that social interaction and imaginative plays are large contributors to the process of cognitive development in children. He believed that the social interactions that children engaged in helped them to both discover and create meaning from the things that they discover. Specifically, he believed that some of the most important learning a child could experience was in the social interactions they had with a skilled tutor that is often an adult, such as a parent or teacher. The child will observe the behaviors of the tutor as well as follow the verbal instructions the tutor provides. The child will then emulate what they observe in their tutor. The child tries to understand what they observe and the instructions they receive by copying and internalizing, while learning to apply them to their own lives. Vygotsky called this collaborative or cooperative dialogue. He called the teacher or tutor in this role the "more knowledgeable other." While this role typically involves adults, as pointed out above, such as teachers, parents, or coaches, it can also involve social interactions with other children. The important part of the role is that it is fulfilled by someone from which the child can learn, a more knowledgeable other.

Vygotsky also proposed something called the "zone of proximal development" and the idea of "scaffolding" in a child's development. The way this works is by recognizing that there are some things a child cannot do independently, but they would be able to do with the assistance of someone else. For example, a child may be developing the ability to make different sounds, but cannot yet talk. With assistance, or scaffolding, from an adult who begins showing them pictures and repeating the names of the pictures, the child will soon begin to develop words and start communicating independently without help. The scaffolding helped them to develop the skills necessary to communicate on their own.

The theory stresses active involvement and interaction between students and their environment which problem-based and discovery-based learning encourages. In the problem-based and discovery-based classroom, the learners are actively involved in the learning process and there is interaction among students, between students and learning materials, between students and teachers, which enhance proper conceptualization and understanding of scientific concepts. Problem-based and discovery-based learning strategies not only offer interaction among students, students are actively involved in the learning process discovering new knowledge on their own with the teacher playing a role of a facilitator. Grouping of students into groups allows students to learn from one another concept they couldn't comprehend independently.

Concept of Problem-based Instructional Strategy

Problem-based learning is an active learning method based on the use of ill-structured problems as a stimulus for learning (Barrows, 2000). Ill-structured problems are complex problems that cannot be solved by a simple algorithm. Such problems do not necessarily have a single correct answer but require learners to consider alternatives and to provide a reasoned argument to support the solution that they generate. In

Problem-based learning, students have the opportunity to develop skills in reasoning and self-directed learning. Empirical studies of problem-based learning have demonstrated that students who have learned from Problem-based learning curricula are better able to apply their knowledge to novel problems as well as utilize more effective self-directed learning strategies than students who have learned from traditional curricula (Hmelo & Lin, 2000; Schmidt, Machiels, Hermans, tenCate, Venekamp, & Boshuizen, 1996).

Gagne (1985) defined problem solving as the "synthesis of other rules and concepts into higher order rules which can be applied to a constrained situation." Gagné (1985) claims that what the learners acquire during the process of problem solving is in a new higher order rule, which is a synthesis of other rules and concepts. In this sense, problem-solving skills include both subject knowledge and general analysis/synthesis skills. A good problem solver has to understand the concepts, rules and principles related to the problems, and the hypthetico-deductive inference skills to generate hypotheses and formulate solutions.

Problem-based learning (PBL) implies learning during problem solving – students focus on a simple or complex problem which does not have only one correct answer readily available from textbook (Hmelo-Silver, 2004). Students can learn individually or divided in groups. Accent is set on "what" to learn to successfully solve the problem (Artino, 2008). Problem-based learning is conceptually based upon the cognitive and constructivist theories. Their specific applications in PBL include connecting new information with prior knowledge, elaboration and construction of information learned and collaborative learning. Students' learning is initiated by a need to solve an authentic problem. In problem-based learning, students are no longer receiving the learning content from the instructor in a “textbook” logical sequence (Jonassen & Hung, 2012).

Problem solving promotes learners’ higher-level thinking skills, and consequently, results in deeper understanding and better application of the knowledge in the future. It is challenging and motivating. This intrinsic motivational component helps increase students’ desire to learn and sustains their interest throughout the course of the learning (Zejnilagic-Hajric, Sabeta & Nuic, 2015).

Traditional instruction usually presents content information with context-free problems. The main shortage of traditional methods is the lack of connection between knowledge learned and real-life practice. As stated in US National Science Education Standards (1996, p. 173), “for students to develop the abilities that characterize science as inquiry, they must actively participate in scientific investigations, and they must actually use the cognitive and manipulative skills associated with the formulation of scientific explanations”. Students tend to develop algorithmic rather than cognitive skills, which leaves student with no choice but memorizing algorithms if they want to survive chemistry course (Cracolice, Deming & Ehlert, 2008).

Many empirical studies were testing the effectiveness of problem-based learning in various contexts and the general conclusion is that problem-based learning enhances students’ problem solving, higher order thinking, self-directed learning skills, and motivation to learn (Zejnilagic-Hajric, Sabeta & Nuic, 2015). Also, problem-based learning students consistently outperformed traditional students on long-term retention assessments (Jonassen & Hung, 2012).

Problem-based learning can be effectively applied in chemistry education, especially in laboratory part of courses. The laboratory is an important component of science education that can foster positive attitudes and interest towards science. Students can learn not only scientific concepts, but also scientific thinking abilities, and experimental skills (Yoon, Woo, Treagust, & Chandrasegaran, 2014). PBL is an alternative to typical laboratory instructional methods because as it can resolve its several shortcomings (Arnold, 2003).

The problem-based learning method requires students to become responsible for their own learning. The problem-based learning teacher is a facilitator of student learning, and his/her interventions diminish as students progressively take on responsibility for their own learning processes. This method is characteristically carried out in small, facilitated groups and takes advantage of the social aspect of learning through discussion, problem solving, and study with peers (Hmelo-Silver, 2004). The facilitator guides students in the learning process, pushing them to think deeply, and models the kinds of questions that students need to be asking themselves, thus forming a cognitive apprenticeship (Collins, Brown & Newman, 1989). As a cognitive apprenticeship, problem-based learning situates learning in complex problems (Hmelo-Silver, 2004). Facilitators make key aspects of expertise visible through questions that scaffold student learning through modeling, coaching, and eventually fading back some of their support. In problem-based learning the facilitator is an expert learner, able to model good strategies for learning and thinking, rather than providing expertise in specific content. This role is critical, as the facilitator must continually monitor the discussion, selecting and implementing appropriate strategies as needed. As students become more experienced with problem-based learning, facilitators can fade their scaffolding until finally the learners adopt much of their questioning role. Student learning occurs as students collaboratively engage in constructive processing.

The approaches recommended by Wood (1975) in implementing problem-based learning in actual classroom teaching-learning process are:

1. Begin with a task embedded in a familiar setting
2. Introduce problem-solving techniques that might be applicable
3. Allow students to create their own paths to a solution
4. Emphasize collaborative learning and problem solving
5. Help develop collaborative working skills
6. Provide different roles for individuals in a group setting
7. Identify, confront and discuss misconceptions.

Wood (1975) further broke down the above approaches into specific steps as follows:

a. **Identify and define the problem**: Instructors ask questions to help students identify the problem under study by interpreting the information provided in the problem statement. This enabled the instructor to isolate what is known to the students from what is unknown to the students.

b. **Analyze the Problem:** Teacher engage students in critical analysis of the problem to discover the root cause of the problem after identifying the problem. Teacher provides learning resources to students to discover the root cause of the problem.

c. **Generate Potential Solution:** Teacher guide students to generate solutions as many as possible. In this stage, there are no wrong answers and judgments are not passed on another's suggestions. At the end of this stage, teacher provides each student enough time to clarify their suggestions for a common understanding for later selection.

d. **Select and Plan Solution:** Teacher guide students to select the best solutions from the wide variety of possible solutions to solve the problem given the circumstances, resources and other considerations. Here the group is trying to figure out exactly what would work best given who they are, what they have to work with, and other considerations that will affect the solution.

e. **Implement the solution:** Teacher guide students to execute the solution. Teacher encourages students to try different strategy if the plan didn't work immediately.

f. **Evaluate the solution:** Teacher encourages students to reflect on the solution. Once a solution has been reached, students should ask themselves the following questions:

- Does the answer make sense?
- Does it fit with the criteria established in step 1?
- Did I answer the question(s)?
- What did I learn by doing this?
- Could I have done the problem another way?

Concept of Discovery-based Instructional Strategy

The discovery-based method is a teaching technique that encourages student to take a more active role in their learning process by answering series of question or solving problems designed to introduce a general concept (Mayer, 2003). Jerome S. Brunner, a highly influential cognitive psychologist is credited for its development into an accepted instructional technique. Bruner's 1966 theory of discovery learning and cognitive development postulates that a leaner is capable of learning any material so long as the instruction is organized appropriately. Bruner's theory suggests a system of coding in which people form a hierarchical arrangement of related theories with each successive level becoming more specific (Mattingly, Lutkehaus & Throop, 2008). The theory provides anchor for discovery-based instruction where learning is organized in a meaningful order such that students on their own and at their own pace can study and acquire knowledge of concepts in proceeding from the known to the unknown. Thus, effective learning involves meaningful organization of materials as is the case with discovery-based instructional approach in which the students discover new fact by answering well thought out questions posed by the teacher in other to solve a particular problem.

The discovery-based method is based on the notion that learning takes place through classification and schema formation (Gallenestiens, 2004). Three main principles guided Brunner's development of this approach.

1. Consideration should be given to experiences and contexts that motivate the students' interest.

2. There should be a spiral organization of the material forcing students to build previously acquired information.

3. The instruction should facilitate extrapolation- constructivist theory.

In this teaching approach, the instructor guides the student's thought process by posing a series of questions whose responses would lead to the understanding of a concept before it is explicitly stated (Ozioko, 2015). Children act as detectives as they solve concept attainment activities in stimulating environments (Gallenstien, 2004). In doing so, they place a newly introduced object in a category that they have previously discovered or identified. This teaching method is believed to increase retention of material because the student organizes the new information that has already been stored.

Discovery-based instructional strategy is one of the modern teaching methods used for teaching in science, technical and vocational education. It is a student-centered approach (Fatokun & Yallams, 2007). Discovery-based method increases the degree of students' interest, innovativeness, problem-solving ability, creativity and consequently improves their achievement in both theory and practice. According to Yallams (2007), discovery occurs when an individual is involved mainly in using his mental processes to mediate some concepts or principles through problem-solving activities. Fatokun and Yallams (2007) described discovery method as a resource based learning which is an innovation that reverses the usual role of the teacher from that which he is the main authority and source of all knowledge to one in which he acts simply as a guide to the students to enable them to make use of other sources of information.

In using Discovery-based method, the teachers were more interested in the creative ability of the learner (Fatokun & Yallams, 2007). Audu (2007) also viewed discovery method as the teaching method that involves an instructional exploration in some problem-solving experience in which the student can draw general conclusions from data which he has gathered through various physical and mental process such as observing, inferring, predicting, communicating, describing and formulating relevant questions. Discovery-based method encourages creativity in learners and discourages rote learning (Ozioko, 2015). Discovery-based learning emphasizes learners take the ideas of the teacher and assimilate them with previous knowledge and experiences to modify it in a more complex way, supporting the construction of new knowledge. The teacher supports learners' personal instruction of knowledge by offering comments, suggestions, feedback or observations. According to Uwameiye and Ogunbemeru (2005), guided discovery method is the method of teaching that has the advantage of allowing learners to use process skills to generate content information. When student are actively engaged in the learning process they are not only able to understand more complex material, but are able to transfer their learning from one problem to another. Discovery method actively engages learners in first hand real world learning. It is characterized by convergent thinking. Discovery method is a Socratic method of teaching which students make inference with a limited amount of guidance from the teacher. The teacher's leading questions allow the students the opportunity to discover principles or explanations (Spence, Jensen & Shepherd, 2004).

Kersh (2004) said that learning by discovery benefits learners for the following reasons: increases the learners' ability to learn related materials, fosters an interest in the activity itself rather than in the rewards which may follow from the learning; develops an ability to approach problems in a way that will more likely lead to a solution and tends to make the material that is learned easier to retrieve or reconstruct. In using guided discovery as a teaching method, the teacher devices series of statements or question that will guide the learners; uses step by step series of discoveries that can lead to a single predetermined goal. This implies that thought provoking topics are introduced as question to enable students discover answers to the problems at hand. The teacher using guided discovery method initiates a stimulus and the learner reacts by engaging in active inquiry thereby discovering the appropriate response.

This method is challenging and facilitates achievement and transfer of what is learned (Ajewole, 1990). Discovery method places the teacher as the overseer and facilitator of learning, and as the mediator between the students and the instructional materials for the lesson. The method is said to have the capacity to promote critical thinking and objective reasoning. In guided discovery learning, learners must be guided along a path toward discovery of ideas, concepts and information. This requires two things (Nwakoha, 2000):

1. A learning design that builds ever-increasing understanding and comprehension in learners without causing frustration or apathy. Challenging yet achievable activities allow learners to stretch their thinking and be successful.

2. A learning facilitator who is a guide rather than a teacher during the learning activities. Facilitators provide initial guidance, monitor progress, steer learners back on track if necessary, ask questions to ensure understanding facilitate feedback when required given positive reinforcement and help learners integrate concept into the

learner's own job responsibility. They are important to the process, but don't interfere with discovery.

Discovery learning takes place in problem-solving situations where the learner draws on his own experience and prior knowledge to discover the truths that are to be learned. Guided discovery is a method of instruction through which students interact with their environment by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments. It is posited that students are more likely to remember concepts they discover on their own than those they are taught. It is constructivist based approach to education. Guided discovery incorporates three models (Wikipedia, 2009):

1. Problem solving: This Model relates to the ways to which we expand our intellect, encountering the environment, processing the data obtained and reorganizing one's own knowledge. It uses small group activities, committee activities, individual study and investigation.

2. Learner Management: The learning must be learner-driven so that participants working alone or in small teams can learn at their own pace.

3. Integrating and Connecting: Learning must encourage the integration of new knowledge into the learner's existing knowledge and clearly connect to the real world. The role of the teacher in an integrated teaching and learning environment is to assist students with making connections and therefore finding meaning through an educational process. This teaching strategy is certainly in keeping with the goals of integration to teach and learn about our world and the knowledge and skills necessary to act responsibly within and upon it.

Teaching students with the notion of discovering, critical thinking, questioning, and problem solving skills is one of the main principles of science and technology teaching. Thus, science and technology teaching curriculum should accordingly be developed to educate science-literate students who are able to inquire and solve problems they face. Today, it is believed that methods in accordance with the constructivist approach in which the students learn more effectively by constructing their own knowledge, should be used. One of these methods is discovery learning.

The basis of science teaching is to understand that natural phenomena and the nature of science require inquiring and discovering. Inquiry in science consists of experiments and inquiring natural phenomena by discovery learning (Bruner, 1966; Lee, Hart, Cuevas & Enders, 2004). Bruner points out that any individual has the "will" to learn and this "will" should be used in such activities that it should raise curiosity and direct students to studying and discovering knowledge. Bruner (1961) stated that learning happens by discovery, which prioritizes reflection, thinking, experimenting, and exploring. People who use self discovery in learning turn out to be more self confident. Discovery is a way from the unknown to the known by the learners themselves (Bruner, 1966). The active participation of the learner in the learning process is called discovery learning (Bruner, 1968; Kara & Ozgun-Koca, 2004; Kipnis, 2005). In discovery learning, students construct knowledge based on new information and data collected by them in an explorative learning environment (De Jong & Van Joolingen, 1998).

Harlen (2004) stated that discovery learning in science develops the perception skills of students because it allows them to understand the natural phenomena and the world by using their cognitive and physical skills. It is suggested that this kind of learning shows students the nature of scientific studies and the ways learning is realized. Thus, it develops their discovery skills (National Research Council (NRC), 2004). Therefore, discovery learning requires active participation of students in the learning process (Matson, 2006).

According to Matson (2006), inquiry and discovery based science teaching is the process of inquiring the nature and structure of the universe. Inquiry and discovery based learning requires students to take examples from daily life, to propose hypotheses, test them like scientists, and meanwhile, to gain advanced level cognitive skills (Matthews, 2002). Discovery learning is a method that encourages students to arrive at a conclusion based upon their own activities and observations. Inclusion of activities based on discovery learning in science teaching in Turkey is important for meaningful and lifelong learning. The activities in science teaching raise the curiosity of students and drive them to inquire their priorities and perceive the natural phenomena from different aspects. Such activities help to correct the conceptual errors of students (Kaptan & Korkmaz, 2000).

According to Wood (1975), the basic processes in discovery-based learning are: a) observing, b) classifying, c) measuring, d) predicting, e) describing and f) inferring as recommended by wood (1975). Justin (2014) the following as the basic steps of implementing discovery-based learning in actual classroom situation:

a. **Define the Problem**: Teacher help students define the problem by asking thought provoking questions. This enhances students in depth understanding of the problem to enable them state feasible hypothesis that guided their discovery of the solution to the problem.

b. **Guide students plan where and how to gather data and information**: Teacher guide, ensure the availability of necessary materials that enabled students to gather and interpret data in his/her quest of solving the problem.

c. Students' present findings through graphs, charts, models, writing etc. Teacher evaluates students' findings to ensure that they are in accordance with scientific ideas. The teachers pointed out the strengths and weaknesses of each student.

The students in the experimental and control groups were post tested two days to the end of the six weeks treatment.

Concept of Academic achievement

Academic Achievement generally refers to the degree or level of success or proficiency attained in some academic work (Arora, 2016). It encourages the students to work hard and learn more. Academic achievement is the status of a student's learning and refers to knowledge attained and skills developed during their academic career which are assessed by school authorities with the help of teacher made or standardized tests. Academic achievement is one of the most important goals of education. The success or failure of a student is measured in terms of academic achievement. It means development of skills in school subjects. Academic Achievement is the criterion for selection, promotion or recognition in various walks of life. Academic Achievement is based on the assumption that there are differences within an individual from time as behavioural oscillations. The academic achievement of the same individual differs from time to time, from one class to another and from, one educational level to another. Kumari (2001) defined academic achievement as the sum total of information gained after completing a course of instruction (partially or fully) in a particular grade that he has obtained on an achievement test. Academic Achievement is one part of the wider term of educational growth. It refers to what a student has achieved in different subjects of studies, during the course of academic year. Academic achievement is affected largely due to the intra individual differences, (differences within the individual from time to time) or with individual differences, i.e. between one individual and another, between one group and another. Besides areas of functioning, individuals of the same group, same grade and same potential ability may differ in their academic proficiency due to many factors. At each stage in the schools some measure of achievement is used as determiner of the student's status and as a basis for decisions about the further opportunities for learning to be provided in subsequent stages.

Empirical Studies on the Effect of Problem-based Instructional Strategy on Students Academic Achievement

In a study on problem-based learning, Ajai, Imoko and O'kwu (2013) compared the effectiveness of problem-based method and conventional method in teaching algebra. This study was undertaken to find out the effect of Problem-Based Learning (PBL) approach on senior secondary school students' achievement in algebra. The design of the study was quasi-experimental pre test - post test control group. Four hundred and forty seven senior secondary one (SS I) students of six grant-aided and government schools sampled using multistage sampling were involved in the study. Two hundred and eleven students were assigned to the experimental group while two hundred and thirty six students were assigned to the control group. Students' Algebra

Achievement Test (SAAT) constructed by the researchers was the main instrument used for data collection. Four hypotheses were raised for the study and tested using Analysis of Covariance (ANCOVA) at .05 level of significance. Findings of the study showed that students taught using PBL achieved significantly higher in the post test than those taught algebra using conventional method. The interaction effects on achievement due to methods and gender was not significant (at $p < .05$). The study proved the efficacy of PBL. This study differs from the current study in the sense that it focused on two methods of teaching while the current studies is on three methods of teaching.

In another study, Ali, Hukamadad, Akhter and Khan (2010) examined the effect of using problem solving method on the achievement of Mathematics students in Pakistan. The major purpose of study was to investigate the effects of using problem solving method on students' achievement in teaching mathematics at elementary level in Pakistan. Pre-test post-test design was used in the study. Results were analyzed using mean, standard deviation and t-test. From the findings it was observed that the use of problem solving method enhanced the achievement of the students in mathematics. The result showed that there was significant difference between the effectiveness of traditional teaching method and problem solving method in teaching of mathematics at elementary level.

The study recommended that the teachers should be encouraged to employ problem solving method in teaching mathematical concepts like set, information handling and geometry etc. Regular training, workshops and seminars should be arranged for teachers to give them knowledge and understanding of problem based learning. Students' achievement in mathematics was the focus of this study which differentiated it from the current study that focused on students' achievement in chemistry.

Celik, Onder and Silay (2011) studied the effects of problem-based learning on students' success in Physics course. The study adopted pre-test post test quasi-experimental design. 44 second year undergraduate students were randomly assigned to experimental group (20 students) in which problem-based learning was used, and control (24 students) in which conventional teaching method was used. Data were obtained through Physics exam which was developed by the researchers. The study concluded that there was a statistically significant difference between the two groups in terms of students' total mean scores in favour of PBL group and PBL is affective on students' Physics achievement.

Anyafulude (2014) investigated the effects of Problem-based and Discovery-based instructional strategies on students' Achievement in Chemistry in Agbani Education Zone of Enugu State. The research adopted a quasi-experimental pre-test, post-test, non-equivalent control group design involving two experimental and one control groups. The sample comprised 375 senior secondary class two Chemistry students from three intact classes randomly drawn from a clustered sample of three senior secondary schools in Agbani Education Zone. The classes were assigned randomly to experimental and control groups. Experimental groups were taught selected topic in Chemistry using problem-based and discovery-based strategies. Control groups were taught the same topic using expository method. Pre-test was administered to both groups before the commencement of the treatment. Treatment was administered for a period of 6 weeks after which a post-test was administered.

Data was collected using two instruments, pre and post-achievement tests in Chemistry duly validated and a reliability co-efficient of .71 obtained using Kuder Richardson 20 (KR – 20) formula. Data were analyzed using mean and standard deviation to answer the research questions while analysis of Covariance (ANCOVA) tested hypotheses at .05 significance level. It was revealed among others that problem-based strategy significantly enhanced students' achievement in Chemistry more than the discovery-based and the expository strategies.

Empirical Studies on the Effect of Discovery-based Instructional Strategy on Students Academic Achievement

Ajewole (1990) conducted a study on the effect of guided discovery method and expository (lecture) instructional methods on students' achievement and interest on SSSI students in algebra. The study was carried out using a pretest- posttest (multivariate) experimental research design. Three validated research instruments and three kinds of lesson plans were used. Purposive and random sampling techniques were used in drawing the subjects of the study which consisted of four hundred and forty seven (447) SSSI students from four secondary schools in Enugu Education Zone of the then Anambra state. There were two experimental groups and one control group in each of the four schools used. One of the experimental groups was taught using G.D.M. The control group was taught using the expository model.

The data obtained from the administration of the research instruments were summarized and analyzed using mean scores, standard deviations and ANCOVA. Results of data analysis showed that:

1. The GDM was effective in fostering students' achievement and interest in algebra.

2. The urban students achieved better than their rural counterparts

3. The students taught with GDM benefited more in algebra than their counterparts

4. The urban students had higher interest in algebra than their rural counterparts

The researchers' use of inexperienced mathematics teachers (fresh mathematics graduates) in teaching the experimental groups and practicing teachers for the control group may have affected the result of the study. The use of highly qualified and experienced mathematics teachers for both experimental and control groups would have been more ideal, for it would have minimized the influence of teacher differences as an extraneous variable in the study. This therefore, underscores the need for this study.

Uwameiye and Ogunbameru (2005) also conducted a research on the effect of guided discovery method (GDM) on the academic achievement of students in Home economics in Egor Local Government Area, Edo State of Nigeria. She developed three research questions and formulated three null hypotheses which were tested at 0.05 level of significance. This research made use of a quasi-experimental design consisting of experimental, control group pre-test, post-test. Home economics achievement test (HEAT) was used to collect data from 9,450 junior secondary school students (JSS II) offering Home Economics in the 52 junior schools in Egor local government area of Edo State.

He made use of mean and standard deviation for answering research questions and t-test statistic for testing the hypotheses. The result of the study showed that students exposed to GDM instruction in Home economic achieved more significant mean scores in Home economics achievement test than the students exposed to lecture method of teaching. It was recommended among others that Home economics teachers should be trained to use GDM instruction as a method of teaching. It was then concluded that GDM instruction is a better method of teaching Home economics at the junior secondary school level.

Okwor (2007) investigated the effects of guided discovery and expository (lecture) methods on students' achievement in Agriculture science. A post-test true experimental design was adopted for the study. Sixty nine (69) SSII students from girls' secondary schools in Nsukka urban were used for the study. The simple random sampling technique was employed to compose the two experimental groups and a control group. The experimental group was taught using guided discovery and control group was taught using expository while the control group was taught using conventional lecture method. The agricultural science achievement test (ASAT) consisting of fifteen (15) items was constructed and used for data collection. The data collected was analyzed using mean, standard deviation and analysis of covariance (ANCOVA). Finding from the study revealed that the students taught using guided discovery teaching method performed significantly better than those taught using conventional method.

Ogbuanya and Usoro (2008) conducted a research on the effects of guided discovery method GDM instructional technique on academic achievement and retention of student in technical drawing in technical colleges in Akwa Ibom State. A quasi experimental pre-test post-test design with an experimental and non-equivalent control group was adopted. The population of the study consisted of 1500 technical year two students in five government technical colleges in Akwa Ibom State. The sample comprised of 100 students drawn from two intact classes selected through a two stage random sampling method. Technical Drawing Achievement Test (TDAT) constructed by the researcher and validated by three experts in the department of vocational teacher education, university of Nigeria, Nsukka was used to collect data for the research. Two research questions and two null hypotheses were formulated.

The study made use of mean and standard deviation to analyze the data for answering the research questions while analysis of covariance (ANCOVA) was used to test the hypotheses at 0.05 level of significance. The study found that the students taught with GDM instructional technique scored higher in the post-test than those taught with conventional lecture method. Also found was that the students taught with GDM instructional technique had a higher mean score than those taught with lecture method in the retention test. It was recommended that technical teachers should always use GDM instructional technique as it caters for the diverse learning styles and needs of the students hence improve their academic achievement and retention of learning.

Suleiman (2008) conducted a research on the effects of GDM on senior secondary school students achievement in electrochemistry. He developed three research questions and formulated three null hypotheses that were tested at probability of 0.05 level of significance. A achievement test on electrochemistry was used to collect data from one hundred and twelve boys and seventy four girls selected from four co-educational secondary schools in Ilorin metropolis. A quasi-experimental design which involved 3x3x2 factorial design was used for the study.

Suleiman (2008) made use of the mean and standard deviation for answering the research questions and ANCOVA for testing the hypotheses. Scheffer's post-hoc analysis was used to determine the direction of difference in the analysis. Findings of the study showed that students in the experimental group taught with GDM achieved significantly better than those in the control group.

Ali (2006) carries out a study in which he used guided discovery and expository (lecture) method of presenting task in reception to achievement of primary school mathematics pupils. He used 17,100 primary 6 (highest grade in the Nigeria primary school) for a duration of three months of instruction in elementary mathematics. Half of these subjects were considered the guided discovery group while the other half was considered the expository (lecturer) group. The teachers specially trained for three weeks introduced the units. A follow up observation and analysis of data made from observing teachers teaching, show equal model. Unique to either treatment D (guided discovery) or treatment E (expository). The result show that the subject in treatment D (guided discovery) achieved better in mathematics than those of treatment E (Expository). It does appear that attempts have not been made to investigate the effect of the GDM on students' achievement in Foods and Nutrition which differ, remarkably from mathematics, so there is need for the study which sought to verify the effect of the GDM on students' achievement and interest in the area of Foods and Nutrition.

Similarly, Iwuchukwu (1984) compared the influence of guided discovery and lecture teaching strategies on form three students achievement in biology test using 180 students. After a pre-test, one group was taught using lecture method and the other group was taught using guided discovery method. Results indicated that students exposed to guided discovery score significantly higher on the post-test than those exposed to lecture treatment.

Saunders and Shepardson (1987) examined the effect of concrete (laboratory & discovery) and formal (lecture and discussion) teaching method on the science achievement of student pre and post – test measures were taken on the dependent features (science achievement) using teacher made test covering the units. The treatment lasted for three months and consisted of 62 students. Analysis of covariance indicated significantly higher achievement by the laboratory and discovery group than the lecture and discussion group.

Uside, Barchok & Abura (2013) studied the effect of discovery method on secondary school students' achievement in Physics in Kenya. This study specifically sought to determine the effects of Discovery Experimental Method (DEM) on secondary school student's achievement in physics in Kenya. The Solomon four group experimental research design was used in the study. The study was carried out in four secondary schools in Uasin Gishu County in Kenya. Students in experimental groups were taught using the DEM while those in control groups were taught using the Teacher Demonstration Method (TDM). Pre-test exam was administered to one experimental group and one control group to determine whether students had any pre-existing knowledge on the topic of cells and simple circuits in the form two physics syllabus. This study established the effects of discovery method (DE) on secondary school students' achievement in physics. The study revealed that the DEM had significant effect on the achievement of students by enhancing knowledge retention and instilling confidence.

Nelson and Frazer (1972) in their study titled "discovery learning vs expository learning: New insight into an old controversy" revealed that students taught with expository method outperformed their counterpart taught with discovery method. 228 seventh graders who had not previously mastered the four geometry concepts-quadri-lateral, rhombus, trapezoid, and parallelogram were the sample for this study. The study adopted 3x3x3 factorial design of the experimental type. A complete description of the experimental procedure is presented. Results show that students in the expository groups spent less time studying the lessons than those in the discovery groups, yet had superior immediate acquisition scores and equal retention scores. The superiority of the expository method is thus indicated, at least for the dimensions measured.

Effect of problem-based and discovery-based Instructional Strategy on Male and Female Students Academic Achievement

Gender refers to the varied socially and culturally constructed roles, qualities behaviour and so on that is ascribed to women and men by different societies (UNICEF, 1990). Nzewi (2010) defines gender as a psychological term describing behaviour and attributes expected of individuals on the basis of being born either male or female. Keller (1991) says gender is a cultural construct developed by the society to distinguish the role, behaviour, mental and emotional characteristic between males and females. Sadiq (1996) says that sex is a physical distinction; gender is a social and cultural one. This implies that roles expectations of males and females are defined by societies and cultures.

Gender differentiation is an old and long controversial issue in education. Difference opinion and view abound on the issue of gender and its effects on student achievement. There are two strong opposing schools of thought as regards to the effect of gender and achievement while some scholars and researchers e.g. Obikese (2007) and Okoro (2011) contend that male student achieve higher than their female counterpart in science. Such scholar include Mayer (2003) who determined the effect of games on mathematics achievement, interest and retention on junior secondary students in Igbo – Etiti L.G.A. He purposely sampled two secondary schools (221 JS2) by simple random sampling. The data collected were analyzed using mean, standard deviation and ANCOVA. The findings revealed that the male students benefited more than their female colleagues. This study is similar to the present study in experimental design and method of data analysis but differs from it in other areas.

The other schools of thought Maduabum (1995), Nzewi (2010), Okeke (2007), are of the view that females achieve as high as their male counterparts when given equal opportunities. Okoro (2011) studied the effect of interaction patterns on achievement and interest in biology among secondary school students, findings from this study indicated that male students achievement and interest score where significantly higher than that of their female counterparts exposed to three (3) interaction patterns (cooperative, competitive and individualistic pattern of learning). In contrary to the findings of Okoro (2011) and Obikese (2007), Maduabum (1995) conducted a research on the effectiveness of the expository and guided discovery on student achievement in biology. Quasi – experimental design was used in carrying out the study which involved 82 first year senior secondary school students (42 males and 40 females). Analysis of the result showed that there were no significant difference in the achievement of male and female exposed to the two groups of teaching method. This study is similar to the present one in experimental design but differs from it in other areas.

Ozioko (2015) investigated the effect of guided discovery method on academic achievement and interest of senior secondary school students in foods and nutrition in Nsukka education zone of Enugu State. The study was carried out to investigate the effect of guided discovery method (GDM) on academic achievement and interest of senior secondary school students in Foods and Nutrition. The effect of gender and location on the achievement and interest of SSS1 students taught using G.D.M was also investigated. Six research questions were generated and 6 null hypotheses formulated to guide the study. After a review of related literature, Quasi experimental design was adopted for the study. The study was carried out in Nsukka educational zone in Enugu state. The population of the study was 16350 SSI students in Nsukka education zone. The sample consisted of 132 Foods and Nutrition SSS1 students which were randomly composed. Questionnaire was used for data collection. Three experts validated the instruments. Kuder Richardson formula 21 and Cronbach Alpha formal methods were used to determine internal consistency of the instruments (FNAT and FNII). The reliability coefficient of .77 and .61 were obtained. The mean score was used to answer research questions and the research hypotheses tested using ANCOVA statistics at .05 level of significance. The major findings of the study were:

1. G.D.M. as a method of teaching was a significant factor of students' achievement in Foods and Nutrition. The group taught with G.D.M achieved higher than the group taught with lecture method.

2. Gender had no significant effect on students' overall achievement in Foods and Nutrition when taught with G.D.M. 3. Location was a significant factor of students' overall achievement in Foods and Nutrition when taught with G.D.M..

Umoh (2001) investigated the effect of games on the achievement and interest of junior secondary school student in Igbo grammar. The insight gained from this study is the finding that gender was a significant factor on student over all achievement in Igbo grammar. The females performed significantly higher than their male counterpart. This study is similar to the present one in experimental design and method of data analysis but differs from it in other areas.

Oluikpe (2004) carried out an experiment to examine the effect of English for academic purposes (EAP) method on the achievement of University of Nigeria Education student in expository writing. The study found out that gender was not a significant factor on student over all achievement in expository writing although the mean achievement score of female was slightly higher than that of their male counterpart.

Udo (2010) investigated the effects of guided discovery, students-centered demonstration and the expository instructional strategies on students' performance in chemistry. This study investigated the relative effectiveness of guided-discovery, student-centred demonstration and expository methods of instruction on students' performance in chemistry. It was a quasi-experimental research using non-randomized-pre-test – post-test control group design with expository method as control. Two research questions and two hypotheses were formulated for answering and testing respectively. A sample of 118 SS2 chemistry students (62 males and 56 females) drawn from 3-co educational public secondary schools in Uyo Local Government Area of Akwa Ibom State was used for the study. Criterion sampling technique was used in selecting the sample. A researcher- developed test – Chemistry Achievement Test

(CAT), with a reliability index of 0.78 determined using test-retest method was used in collecting relevant data. After classroom investigations, the results indicated that guided discovery was the most effective followed by student-centred demonstration. The results further revealed that gender had no significant effect on students achievement in chemistry when taught using guided discovery.

Anyafulude (2014) investigated the effects of Problem-based and Discovery-based instructional strategies on students' Achievement in Chemistry in Agbani Education Zone of Enugu State. The research adopted a quasi-experimental pre-test, post-test, non-equivalent control group design involving two experimental and one control groups. The sample comprised 375 senior secondary class two Chemistry students from three intact classes randomly drawn from a clustered sample of three senior secondary schools in Agbani Education Zone. The classes were assigned randomly to experimental and control groups. Experimental groups were taught selected topic in Chemistry using problem-based and discovery-based strategies. Control groups were taught the same topic using expository method. Pre-test was administered to both groups before the commencement of the treatment. Treatment was administered for a period of 6 weeks after which a post-test was administered. Data was collected using two instruments, pre and post-achievement tests in Chemistry duly validated and a reliability co-efficient of .71 obtained using Kuder Richardson 20 (KR – 20) formular. Data were analyzed using mean and standard deviation to answer the research questions while analysis of Coveriance (ANCOVA) tested hypotheses at 0.05 significance level. It was revealed among others that problem-based strategy significantly enhanced female students' performance than male counterparts.

Ozomadu (2016) investigated the effectiveness of guide discovery and expository methods on students' achievement in senior secondary school mathematics. The study was designed to compare the effect of Guided Discovery and Expository methods on students' achievement. Two research questions and three research hypothesis guided the study. A non-equivalent control group design was adopted for the study. A sample of 160 Senior Secondary School (SS2) Mathematics students was used for the study. For the Guided Discovery treatment group, a total of 81 SS2 students were used while for the Expository group, a total of 79 SS2 students were used for the study. The instrument was mathematics achievement test on algebra (MATA). It was developed and used for both pretest and posttest. MATA was validated by four experts in Mathematics education and educational measurement and evaluation. The reliability of the instrument was 0.60 using Pearson Product Moment Correlation coefficient method. The research questions were answered using mean and standard deviations. The hypotheses were tested at 0.05 level of significant using analysis of Covariance (ANCOVA). The study revealed that the Guided Discovery of teaching was more effective in enhancing student's achievement in algebra. There was significant gender difference in enhancing students' in MATA. Interaction effect of gender and method on student's achievement is significant.

Jegede and Fatoke (2014) studied the effects of problem-solving instructional strategy, three modes of instruction and gender on learning outcomes in chemistry. The study was designed to investigate the effects of problem-solving instructional strategy, three accompanying modes of instruction (i.e. Remediation, Feedback and Practice) and gender on learning outcomes in chemistry. A pre-test post-test control group quasi experimental design was adopted for the study. Data were collected from a sample of 210 SS2 Chemistry Students made up of 109 males and 101 females selected from six schools in three (3) Local Government Areas of Ekiti State, Nigeria based on multi-stage random sampling techniques. The Seven Step Chemistry Problem-Solving Model as suggested by Frazer (1981) and Selvarantnam (1983) was adopted for the study. The experiment was carried out on four (4) groups of Students. The Students in experimental groups 1 and 2 were exposed to Problem-Solving approach coupled with remediation and feedback respectively, experimental group 3 was exposed to Problem-Solving coupled with practice. The fourth group not treated formed the control group. Analysis of Covariance (ANCOVA) was used to analyse the data with the pretest scores as covariates. The findings revealed that students in experimental group 1 (i.e. Problem-Solving coupled with remediation) had the highest performance in Chemistry Achievement Test (CAT) followed by those exposed in experimental group 2 and 3 respectively (i.e. Problem-Solving coupled with feedback and practice respectively).However, the control group had the least performance in Chemistry Achievement Test (CAT). The findings also revealed that gender had no significant impact on students' achievement in chemistry.

Nekang (2013) investigated the effect of Rusbult's Problem Solving Strategy (RUPSS) on secondary school students' achievement in trigonometry in Fako Division in Cameroon. A sample of 366 form four students consisting of 186 males and 180 females were drawn from three colleges in the division by a multi-stage sampling technique. The Trigonometry Achievement Test (TAT) was used for data collection. Five experts, three in mathematics education and two in measurement and evaluation validated the instrument. The findings showed that Students exposed to the RUPSS achieved higher than those exposed to CPSS; Males in the RUPSS obtained a higher POSTTAT mean score compared to their female counterparts. The findings also revealed that there is no statistically significant interaction effect between gender and strategy as measured by the mean achievement scores of TAT.

Dania (2014) investigated the effect of gender on students' academic achievement in secondary school Social Studies. The study adopted a quasi-experimental design (2x2 non-randomized pre-test, post-test control group) comprising six groups made up of four experimental groups and two control groups. Six schools and one hundred and eighty (180) Upper basic 2 students in Delta and Edo States made up the sample for the study. Six intact classes were randomly selected and assigned to experimental and control groups. The instrument used in this study is the achievement instrument tagged "Social Studies Achievement Test" (SSAT). The validity and reliability of these instruments were established. The reliability of the instruments was established using Pearson product moment correlation coefficient (r). And the reliability coefficients obtained was 0.79. Means, Standard Deviation, Analysis of covariance (ANCOVA) Result revealed that: gender (male/female) had no significant effect on students' achievement in Social Studies and finally, result showed that there was significant interaction effect of treatment and gender on students' academic performance in Social Studies.

Effect of Problem-based and Discovery-based Instructional Strategy on Urban and Rural Students Academic Achievement

School location is concerned with the area where a school is located; schools are located in different areas due to need or availability of land. School can be located in urban or rural areas in Nigeria (Okeke, 2000). The location of a school affects the provision and use of different facilities for teaching and learning.

Oluikpe (2004) investigated the conceptual development of the co-ordinate references system of Nigeria Igbo students. She used 192 boys and girls of age range 8-19 years from schools in Nsukka Local Government Area. They were individually tested on three Piagetian type special tasks. The water line Task (Horizontal), the orange Tray Task (Horizontal) and the vertical Tasks as well as the picture – interpretation Task. The orange Tray Task and the picture Interpretations Task were newly designed and African in orientation. She obtained a very poor result with no group obtaining a 50% pass at any age/grade level in the three tasks. Sex differences were significant in favour of boys and for the two horizontal tasks. There was also a significant difference in achievement between the more familiar orange Tray Task and the less familiar water-line task. There were no significant differences between urban and rural subjects on any of the four tasks. She concluded that achievement of rural subjects was not significantly difference from that of the urban subjects.

In the contrary, in their research entitled, "sex-role and community variability in test performance", MacGregor and Elliot (2002) concluded that school location had a moderating influence upon the performances of junior high school students in cognitive and non-cognitive instruments. Obioma (2004) studied the achievement of students in mathematics and revealed that there was no related location difference on the achievement of students. On the contrary, Obioma (2004) revised the result by showing that school location was significant beyond 0.001 in mathematics achievement of students.

In another study titled "Urban and Rural background of first year university students in relation to their academic performance", Dale and Miller (1972) reported that students from city school made the best progress in their first year at the university than those from rural or village schools. At home front, the above observations were reinforced by research reports as well. For instance, Izuwa, (1974) compared the academic achievement of rural and urban primary six pupils in East Central State of Nigeria. He concluded that urban primary six pupils obtained more credit level than rural primary six pupils while there was no significant difference between the urban and rural pupils at pass level. This is why Borg (2007) stressed that although intelligence may be inherited, school achievement is apparently determined to a substantial degree by environment. This present study will either enforce or refute the areas of controversy since there are inconsistent research reports with respect to the influence of location on achievement in some subject areas.

Nbina and Joseph (2011) assessed the effects of problem solving instructional strategies on students' achievement and retention in Chemistry. They reported a study focused on how problem solving instructional strategies would affect students' achievement and retention in Chemistry with particular reference to River State. A pre-test, post-test, non-equivalent control group design was adopted. Two research questions and two hypotheses were respectively answered and tested. Purposive and stratified random sampling was used to select 428 SS II students from two rural and two urban local government areas of Rivers State. These students were randomly assigned to the two treatment groups. Problem solving with Model and Feedback – Correctives (PF), Problem solving with Model Only (PM), and the control Problem

Solving by the Conventional Method (PC). The model used is a Generic Problem Solving Inquiry Model developed by Hungerford (1975). A researcher developed and modified instrument, Chemistry Achievement Test (CAT) and lesson plans were used for the study. Data collected were analyzed using Mean, Standard Deviation (SD) and some gains of achievement and retention and that the hierarchical order of achievement is PF, PM and PC. No significant differences were observed in the post-test mean scores of urban and rural subjects in the achievement is PF, PM and PC. No significant differences were observed in the post-test mean scores of urban and rural subjects in the achievement and retention tests administered in the course of the study. Based on the findings, it is recommended that both rural and urban Chemistry teachers use problem solving instructional strategies, particularly that in which use of a model is supplemented with feedback-correctives in teaching.

Ozioko (2015) investigated the effect of guided discovery method on academic achievement and interest of senior secondary school students in foods and nutrition in Nsukka education zone of Enugu State. The study was carried out to investigate the effect of guided discovery method (GDM) on academic achievement and interest of senior secondary school students in Foods and Nutrition. The effect of gender and location on the achievement and interest of SSS1 students taught using G.D.M was also investigated. Six research questions were generated and 6 null hypotheses formulated to guide the study. After a review of related literature, Quasi experimental design was adopted for the study. The study was carried out in Nsukka educational zone in Enugu state. The population of the study was 16350 SSI students in Nsukka education zone. The sample consisted of 132 Foods and Nutrition SSS1 students which were randomly composed. Questionnaire was used for data collection. Three experts validated the instruments. Kuder Richardson formula 21 and Cronbach Alpha formal methods were used to determine internal consistency of the instruments (FNAT and FNII). The reliability coefficient of .77 and .61 were obtained. The mean score was used to answer research questions and the research hypotheses tested using ANCOVA statistics at .05 level of significance. The major findings of the study were:

1. G.D.M. as a method of teaching was a significant factor of students' achievement in Foods and Nutrition. The group taught with G.D.M achieved higher than the group taught with lecture method.

3. Location was a significant factor of students' overall achievement in Foods and Nutrition when taught with G.D.M..

Appraisal of Reviewed Literature

Students underachievement in chemistry is a now a major problem in the teaching and learning process at the senior secondary school level. Research has shown that students' achievement in chemistry is poor. Reviewed works showed that some of the factors that influence students' achievement in chemistry are teaching approaches, gender and location. Scholars argued that lecture method used by teachers is responsible for poor achievement among secondary school chemistry students.

Problem-solving as a teaching strategy embodies most of the techniques and learning skills science educators consider important when learning science (chemistry) by the investigative methods. On the other hand, discovery is the mental process of assimilating concepts and principles through the processes of observing, classifying, measuring, predicting, describing and inferring. The theories that support this work are

Piaget's and Vygotsky's cognitive development theory which argue that meaningful learning takes place by the assimilation of new concepts and propositions into existing concepts due to the interaction between the learner and environment and that learning is an active process and thus learners should be active participants in teaching-learning process respectively. Learners should be encouraged to construct their own meaning. Problem-based and discovery-based instruction allows students to incorporate new concepts and ideas into broader concepts and by so doing are actively engaged in knowledge construction and making their own meaning.

Evidence from the reviewed literature showed that problem-based and discovery-based instructions are effective in boosting students' achievement. The literatures reviewed were not conclusive about the effect of problem-based and discovery-based instructional strategies on students' achievement. Most of the studies however found significant impact of both problem-based and discovery-based instructional strategies on students' achievement. However, none of the studies to the researchers' best of knowledge have been carried out in the subject area of chemistry in Delta Central Senatorial District of Delta State.

Furthermore, it is observed from the literature reviewed that gender and school location can affect achievement in chemistry. The issue on gender, school location and academic achievement in chemistry centers generally on the extent to which females and males, students in urban and rural schools perform differently in the subject. The issue of influence of gender, school location on students' achievement in chemistry is found to be largely inconclusive in the literature reviewed. Therefore, the need for this current study becomes imperative as it may help provide additional empirical evidence on the influence of gender, school location on students' achievement in chemistry. It is this gap this study seeks to fill.

CHAPTER THREE

RESEARCH METHOD AND PROCEDURE

This chapter presents the description of the methods and procedures that were used in the study. The chapter is organized under the following sub-headings: research design, population of the study, sample and sampling techniques, instrument for data collection, validity of the instrument, reliability of the instrument, treatment procedure and method of data analysis.

Research Design

The study adopted a quasi-experimental design. Specifically, the non-equivalent control group, pretest, post-test design was adopted. The quasi – experimental design was used since the class of students that were used had already been organized into intact classes to provide for stability and avoid disruption of class lessons and class arrangement. In support of this design, Borg and Gall (2007) stated that it is a suitable alternative to experimental design when randomization is not used or applied. According to Ali (2006), quasi-experimental research design can only be used where the researcher cannot randomly sample and assign his subjects to groups. In the study, treatments with the use of problem-based and discovery-based instructional strategies were administered to the experimental groups and the lecture method for the control group. The effects of the methods were then compared. The design is presented in Table 1:

Table 1: Tabular Representation of Design

Group	Pre-test	Treatment	Post-test
Problem-based instruction	O_1	X_p	O_2
Discovery-based instruction	O_3	X_d	O_4
Lecture method (control)	O_5	X_c	O_6

Where,

O_1 = pretest of problem-based instruction group

O_2 = post-test of problem-based instruction group

O_3 = pretest of discovery-based instruction group

O_4 = post-test of discovery-based instruction group

O_5 = pretest of lecture method group

O_6 = post-test of lecture method group

X_p = treatment using problem solving instructional strategy

X_d = treatment using discovery instructional strategy

X_c = treatment of control group

Population of the Study

The population of the study is targeted at all senior secondary two (SS11) chemistry students in Delta Central Senatorial District of Delta State. There are 179 public secondary schools with a total population of 8945 SSII chemistry students comprising of 4668 females and 4277 males (See Appendix H). The senior secondary two (SS11) students were used for the study because they had already been selected into specific discipline and also they were available to be used at any point in time, since they were not preparing for any external examination.

Sample and Sampling Technique

The samples of the study consisted of six (6) mixed senior secondary schools, six chemistry education graduate teachers, six (6) senior secondary school class II (SS II) science classes, that is, one class per school and 316 SS II students from six (6) public secondary schools in Delta Central Senatorial District of Delta State.

The six (6) mixed public secondary schools were selected using stratified sampling technique. First, the public schools in Delta Central Senatorial District were grouped into two; urban and rural schools. Then three (3) schools each were randomly selected from each group. The choice of stratified sampling is to ensure that the different schools constituting both urban and rural areas are adequately represented.

The distribution of samples by location is shown in Table 2:

Table 2: Distribution of Samples by Location

Groups	**Towns/Villages**	**Location**	**Number of Students**		**Total**
			Male	**Female**	
Okpe grammar school	Sapele	Urban	22	38	60
Adeje secondary school	Adeje	Rural	27	25	52
Alegbon secondary school	Effurun	Urban	29	24	53
Opete secondary school	Opete	Rural	17	33	50
Agbarho grammar school	Agbarho	Urban	12	39	51
Okparabe secondary school	Okparabe	Rural	28	22	50
Total			135	181	316

Note: schools located in villages are classified as rural schools and those located in towns are classified as urban schools based on availability of social amenities and infrastructural facilities.

Instrument for Data Collection

Chemistry achievement test (CAT) drawn from a six week instructional unit (research intervention) on chemistry covering the following topics: (1) electronic structure and occurrence of nitrogen; (2) laboratory and industrial preparation of nitrogen, (3) physical and chemical properties of nitrogen and uses of nitrogen, (4) Haber process of the preparation of ammonia, (5) physical and chemical properties of ammonia and (6) uses of ammonia (see Appendix A, B, C) is the instrument used for data collection in this study. The (CAT) consisted of 50 multiple choice test items constructed by the researcher and drawn from the 6 weeks instructional unit (See Appendix D).

Validity of the Instrument

The face validity of the chemistry achievement test (CAT) was done by a panel of three experts made of one Science Educator in Chemistry in Delta State University Abraka, one experienced Chemistry teacher drawn from a school in Warri South Local Government Area of Delta State and an expert in Measurement and Evaluation from Delta State University Abraka. The researcher gave copies of the initial drafts of the chemistry achievement test (CAT), six weeks instructional units, research questions, hypotheses and purpose of the study to the validates. These validates were requested to vet the items in the CAT for clarity of words, plausibility of the distracters, appropriateness to the level of the students and the appropriateness of the six weeks instructional units. They determined the face validity of the CAT instrument by critically examining the test items and relating them to the content of the 6 weeks instructional units. Their corrections include: the expansion of the instructional units from 4 weeks to 6 weeks, instructional units for the problem and discovery-based group should inculcate more students' activities, the preliminary information on the CAT is incomplete and another distracters for question 21 should be found since the answer to the question is so obvious. Thereafter, their corrections and suggestions were effected in the instrument. The panel's approval of the test items as being able to measure what it intends to measure led to the use of the instrument for the study.

The content validity of the instrument was done using a table of specification which ensures that the questions covers all contents in the six weeks instructional units per unit time spent on that content, that is, the higher the time specified on a content in the chemistry scheme of work, the more questions formed from that content as shown in Table 3.

Table 3: Table of specification on Chemistry Achievement Test (CAT)

Content Area	Sub units (%)	Mental Skills						
		Lower Order		Higher Order				
		Knowledge (30%)	Comprehension (22%)	Application (14%)	Analysis (14%)	Synthesis (10%)	Evaluation (10%)	Total (100%)
Nitrogen	Nitrogen (N) (8%)	2	1	1				4
	Laboratory/industrial preparation of nitrogen (20%)	3	1	2	2	2		10
	Uses, physical/chemical properties of N (20%)	3	2	1	1		3	10
Compounds of Nitrogen	Ammonia (16%)	3	3	1		1		8
	Industrial preparation (20%)	2	2	1	3	1	1	10
	Uses (16%)	2	2	1	1	1	1	8
Total		15	11	7	7	5	5	50

Reliability of the Instrument

The reliability of the CAT was established using the Kuder-Richardson 21 formula method. The rationale behind this method is that it is most appropriate for objective test items with multiple options. The instrument was administered to 30 chemistry students in a school in Warri South Local Government Area of Delta State who are outside the area of coverage for the study and the obtained scores were subjected to the Kuder-Richardson 21 formula (See Appendix G).

On analysis of the test scores using Kuder-Richardson 21 formula, a reliability index of 0.83 was obtained. This proved that the instrument was reliable and thus suitable for the study. The reliability index of 0.83 found perfectly agreed with the established standard as recommended by Thorndike and Hagen (1997), Johnson and Christensen (2000), Borich (2004) and Leedy and Ormrod (2005) that reliability has to do with accuracy and precision of a measurement procedure, a high reliability value of 0.70 or higher shows that the test is reliable (accurately) measuring the characteristics it was designed to measure. With all these findings about the instrument, it was administered on the subjects.

Treatment Procedure

Training of instructors

Four of the six instructors that were used for the study were trained on the skills of using problem-based and discovery-based method for teaching for four days lasting for two hours per day. Two other specialists on instruction joined the researcher in training the instructors on the skills of problem solving and discovery method. The first day was spent on discussing the theories, origins and characteristics of the two instructional strategies (problem-based and discovery-based instruction). On the second day, the instructors were trained using the training manuals developed by the researcher; one each for problem and discovery-based instructional strategies. The instructors for each of the teaching strategies were trained separately by different resource persons. The training manuals specified the various steps in using problem and discovery-based instructional strategies. It equally specified the roles teachers and students play in each stage. The third and fourth days was spent on practice and generation of ideas on how to apply problem and discovery-based instructional strategies in the teaching of the selected chemistry concepts. The training came to a close when the researcher and the two other resource persons are convinced that the chemistry teachers trained can accurately apply problem and discovery-based strategies in teaching the selected concepts.

Step by step treatment procedure

The treatment groups consisted of:

a) Experimental groups (problem-based and discovery-based method group); and

b) Control group (lecture method group)

A week before the commencement of treatment, all the six chemistry instructors that were used for the study was given extracts which contained the contents in the six weeks instructional unit. The extracts were taken from New School Chemistry for senior secondary Schools by Ababio (2009). Lesson notes written on each of the concepts in the 6 week instructional unit using the problem and discovery-based instructional strategies formats were given to the specific teachers assigned to use the various instructional strategies for teaching. This was done to ensure that all the instructional presentations followed the recommended format for the designated classes. The lesson notes specified both the teachers and students activities during instruction (see Appendix A & B).

Two days before the commencement of instruction, both the experimental and control groups were pre-tested with the 50 items Chemistry Achievement Test (CAT). This was done to determine the equivalence of the groups before treatment and be sure that any noticed change later was due to the treatment. On treatment, for the control group, each and all the contents in the 6 week instructional unit were presented to the students using lecture method. The two teachers who taught the control groups equally presented the content materials to the students in their final forms. In the experimental classrooms where problem-based and discovery-based instructional strategies were applied, the following steps were followed.

Problem Solving Classroom: In the problem-solving classroom, the teachers who taught there performed the following activities by applying the approaches recommended by Wood (1975) strictly. The approaches are as follows:

8. Begin with a task embedded in a familiar setting
9. Introduce problem-solving techniques that might be applicable
10. Allow students to create their own paths to a solution
11. Emphasize collaborative learning and problem solving
12. Help develop collaborative working skills
13. Provide different roles for individuals in a group setting
14. Identify, confront and discuss misconceptions.

Specifically, the problem solving process recommended by Wood (1975) that was used by the trained instructor in the problem-based instructional strategy classroom are as follows:

g. **Identify and define the problem**: Instructors ask questions to help students identify the problem under study by interpreting the information provided in the problem statement. This enabled the instructor to isolate what is known to the students from what is unknown to the students.

h. **Analyze the Problem:** Teacher engage students in critical analysis of the problem to discover the root cause of the problem after identifying the problem. Teacher provides learning resources to students to discover the root cause of the problem.

i. **Generate Potential Solution:** Teacher guide students to generate solutions as many as possible. In this stage, there are no wrong answers and judgments are not passed on another's suggestions. At the end of this stage, teacher provides each student enough time to clarify their suggestions for a common understanding for later selection.

j. **Select and Plan Solution:** Teacher guide students to select the best solutions from the wide variety of possible solutions to solve the problem given the circumstances, resources and other considerations. Here the group is trying to figure out exactly what would work best given who they are, what they have to work with, and other considerations that will affect the solution.

k. **Implement the solution:** Teacher guide students to execute the solution. Teacher encourages students to try different strategy if the plan didn't work immediately.

l. **Evaluate the solution:** Teacher encourages students to reflect on the solution. Once a solution has been reached, students should ask themselves the following questions:

- Does the answer make sense?
- Does it fit with the criteria established in step 1?
- Did I answer the question(s)?
- What did I learn by doing this?
- Could I have done the problem another way?

Discovery method classroom: The teacher in the discovery-based instructional strategy group incorporated the basic processes of discovery learning into the group's experience: a) observing, b) classifying, c) measuring, d) predicting, e) describing and f) inferring as recommended by Wood (1975). The basic steps that were adopted by teachers in the discovery-based instructional strategy group as recommended by Justin (2014) are as follows:

d. **Define the Problem**: Teacher help students define the problem by asking thought provoking questions. This enhances students in depth understanding of the problem to enable them state feasible hypothesis that guided their discovery of the solution to the problem.

e. **Guide students plan where and how to gather data and information**: Teacher guide, ensure the availability of necessary materials that enabled students to gather and interpret data in his/her quest of solving the problem.

f. Students' present findings through graphs, charts, models, writing etc. Teacher evaluates students' findings to ensure that they are in accordance with scientific ideas. The teachers pointed out the strengths and weaknesses of each student.

The students in the experimental and control groups were post tested two days to the end of the six weeks treatment.

Method of Data Analysis

All the research questions were answered using descriptive statistics (Mean and Standard deviation). The hypothesis 1 was tested for significance using Analysis of Variance (ANOVA). Hypotheses 2, 3, 4 and 5were tested for significance using independent sample t-test. Hypotheses 6, 7 and 8 were tested for significance using Analysis of Covariance (ANCOVA). The hypotheses were tested at 0.05 level of significance.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION

This chapter presents the analysis of the data gathered from the students through the chemistry achievement test (CAT).

Presentation of Results

The results of the analysis are presented in the tables with the interpretation of the results following immediately after the tables. The results of the data analysis are presented in accordance with the research questions and hypotheses raised to guide the study.

Research Question 1

Is there any difference in the mean achievement scores among students taught chemistry using problem-based, discovery-based and lecture methods?

Table 4: Mean pre-test and posttest achievement scores among students taught chemistry using problem-based, discovery-based and lecture method

Group	N	Pretest		posttest		Mean Gain
		Mean	SD	Mean	SD	
Problem-based strategy	112	20.04	7.24	50.89	12.42	30.85
Discovery-based strategy	103	20.68	7.14	41.84	12.83	21.16
Lecture method	101	20.35	7.43	38.61	8.31	18.26

The data in table 4 shows that the three groups were originally at the same level of achievement with a pretest mean achievement scores of 20.04, 20.68 and standard deviation of 7.24 and 7.14 for problem-based and discovery-based instructional strategies respectively (experimental groups) and a pretest mean achievement score of

20.35 and standard deviation of 7.43 for the control group. This implies that all the groups in the experimental and control groups were equivalent on the knowledge of the concepts taught before treatment by mere comparison of the means. For the posttest, the experimental groups obtained a higher mean score of 50.89 with a standard deviation of 12.42 for problem-based instructional strategy and a mean score of 41.84 with a standard deviation of 12.83 for discovery-based instructional strategy. The control group (lecture method) obtained a mean achievement score of 38.61 with a standard deviation of 8.31. Table 4 indicated that students taught with problem-based instructional strategy scored the highest marks. This was followed by students taught with discovery-based instructional strategy and lecture method (control) groups respectively. All the experimental groups (problem-based and discovery-based instructional strategies) scored higher marks than the control group (lecture method).

Hypothesis 1

There is no significant difference in the mean achievement scores among students taught chemistry using problem-based, discovery-based and lecture methods.

Table 5: ANOVA comparison of pre-test scores of problem-based, discovery-based instructional strategies (experimental) and lecture (control) groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21.634	2	10.817	.205	.815
Within Groups	16540.075	313	52.844		
Total	16561.709	315			

The ANOVA comparison of the groups as shown in Table 5 indicated non-significant difference, $F(2, 313) = 0.205$, $P(0.815) > 0.05$. This implies that there is no significant difference in the pre-test scores of the three groups compared. Hence, ANOVA was used to test hypothesis 1.

Table 6: ANOVA comparison of post-test scores of problem-based, discovery-based instructional strategies (experimental) and lecture (control) groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8729.717	2	4364.858	33.472	.000
Within Groups	40816.169	313	130.403		
Total	49545.886	315			

A significant difference was found between the group taught with problem-based, discovery-based instructional strategies and lecture method as shown in Table 6, F (2, 313) = 33.472, P(0.000) < 0.05. Therefore the null hypothesis was rejected. Thus, there is a significant difference in the mean achievement scores among students taught chemistry using problem-based, discovery-based instructional strategies and lecture methods.

Table 7: Scheffe's Post-Hoc test to compare the experimental and control groups

(I) Method	(J) Method	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Problem-Solving	Discovery Method	9.048*	1.559	.000	5.21	12.88
	Lecture Method	12.279*	1.567	.000	8.42	16.13
Discovery Method	Problem-Solving	-9.048*	1.559	.000	-12.88	-5.21
	Lecture Method	3.231	1.599	.132	-.70	7.16
Lecture Method	Problem-Solving	-12.279*	1.567	.000	-16.13	-8.42
	Discovery Method	-3.231	1.599	.132	-7.16	.70

The scheffe's post-hoc analysis shows that there is a significant difference in the mean achievement scores of students taught chemistry using problem-based instructional strategy and those taught using discovery-based instructional strategy in favour of problem-based instructional strategy. There is also a significant difference in the mean achievement scores of students taught chemistry using problem-based instructional strategy and those taught using lecture method in favour of problem-based instructional strategy. There is also a significant difference in the mean achievement scores of students taught chemistry using discovery-based instructional strategy and those taught using lecture method in favour of discovery-based instructional strategy. Table 7 shows that out of the three methods, problem-based instructional strategy proved most effective.

Research Question 2

Is there any difference in the mean achievement scores of students taught chemistry using discovery-based instructional strategy in urban and rural area?

Table 8: Mean pre-test and posttest achievement scores of students taught chemistry using discovery-based instructional strategy in urban and rural area

Location	N	Pretest		Posttest		Mean
		Mean	SD	Mean	SD	Gain
Urban	53	19.62	6.99	44.06	14.25	24.44
Rural	50	21.80	7.19	39.50	10.80	17.70

Table 8 shows a pretest mean achievement score of 19.62 with a standard deviation of 6.99 for urban students while rural students had a pretest mean achievement score of 21.80 with a standard deviation of 7.19. This implies that the two groups were originally not at the same level of achievement. On the posttest scores, table 8 indicated that the urban students had mean achievement score of 44.06 with a standard deviation of 14.25 while the rural students had a mean achievement score of 39.50 with a standard deviation of 10.80. The urban students had a mean gain of 24.44 as compare to rural students with a mean gain of 17.70. Therefore, urban students performed better than rural students in chemistry when taught using discovery-based instructional strategy.

Hypothesis 2

There is no significant difference in the mean achievement scores between students taught chemistry using discovery-based instructional strategy in urban and rural area.

Table 9: Summary of independent t-test comparison of posttest mean achievement scores of students taught chemistry using discovery-based instructional strategy in urban and rural area

Location	N	$\bar{x}$	SD	DF	t-cal.	t-cri.	Sig. (2-tailed)	Decision
Urban	53	44.06	14.25					
				101	1.82	1.98	0.072	Not Significant
Rural	50	39.50	10.80					

Table 9 shows that there was no significant difference in the mean achievement scores between students taught chemistry using discovery-based instructional strategy in urban and rural area, T = 1.821, P(0.072) > 0.05. Thus, the null hypothesis was retained since t-calculated value (1.82) is less than t-critical value (1.98). Therefore, there is no significant difference in the mean achievement scores of students taught chemistry using discovery-based instructional strategy in urban and rural area.

Research Question 3

Is there any difference in the mean achievement scores of students taught chemistry using problem-based instructional strategy in urban and rural area?

Table 10: Mean pre-test and posttest achievement scores of students taught chemistry using problem-based instructional strategy in urban and rural area

Location	N	Pretest		Posttest		Mean
		Mean	SD	Mean	SD	Gain
Urban	60	20.25	6.85	52.75	10.59	32.50
Rural	52	19.81	7.73	48.75	14.03	28.94

Table 10 shows a pretest mean achievement score of 20.25 with a standard deviation of 6.85 for urban students while rural students had a pretest mean achievement score of 19.81 with a standard deviation of 7.73. This implies that the two groups were originally not at the same level of achievement. On the posttest scores, table 10 indicated that the urban students had mean achievement score of 52.75 with a standard deviation of 10.59 while the rural students had a mean achievement score of 48.75 with a standard deviation of 14.03. The urban students had a mean gain of 32.50 while the rural students had a mean gain of 28.94. Therefore, urban students performed better than rural students in chemistry when taught using problem-based instructional strategy.

Hypothesis 3

There is no significant difference in the mean achievement scores between students taught chemistry using problem-based instructional strategy in urban and rural area.

Table 11: Summary of independent t-test comparison of posttest mean achievement scores of students taught chemistry using problem-based instructional strategy in urban and rural area

Location	N	$\bar{x}$	SD	DF	t-cal.	t-cri.	Sig. (2-tailed)	Decision
Urban	60	52.75	10.59					
				110	1.72	1.98	0.089	Not Significant
Rural	52	48.75	14.03					

Table 11 shows that there was no significant difference in the mean achievement scores between students taught chemistry using problem-based instructional strategy in urban and rural area, T = 1.715, P(0.089) > 0.05. Thus, the null hypothesis was retained since t-calculated value (1.72) is less than t-critical value (1.98). Therefore, there is no significant difference in the mean achievement scores of students taught chemistry using discovery-based instructional strategy in urban and rural area.

Research Question 4

Is there any difference in the mean achievement scores of male and female students taught chemistry using discovery-based instructional strategy?

Table 12: Mean pre-test and posttest achievement scores of male and female students taught chemistry using discovery-based instructional strategy

Gender	N	Pretest		Posttest		Mean
		Mean	SD	Mean	SD	Gain
Male	46	21.09	7.30	39.57	11.39	18.48
Female	57	20.35	7.06	43.68	13.71	23.33

In table 12, the male posttest mean score is 39.57 with a pretest mean score of 21.09 and mean gain of 18.48 and the females had a posttest score of 43.68 with pretest mean score of 20.35 and mean gain of 13.33 when exposed to discovery-based instructional strategy. The overall mean difference between the genders is -2.32. This showed that the female students scored higher than their male counterparts.

Hypothesis 4

There is no significant difference between the mean achievement scores of male and female students taught chemistry using discovery-based instructional strategy.

Table 13: Summary of independent t-test comparison of posttest mean achievement scores of male and female students taught chemistry using discovery-based instructional strategy

Gender	N	$\bar{x}$	SD	DF	t-cal.	t-cri.	Sig. (2-tailed)	Decision
Male	46	39.57	11.39					
				101	1.63	1.98	0.11	Not Significant
Female	57	43.68	13.71					

Table 13 shows that there was no significant difference between the mean achievement scores of male and female students taught chemistry using discovery-based instructional strategy, T = 1.633, P(0.11) > 0.05. Thus, the null hypothesis was retained since t-calculated value (1.63) is less than t-critical value (1.98). This implies that there is no significant difference between the mean achievement scores of male and female students taught chemistry using discovery-based instructional strategy. The treatment using discovery-based instructional strategy is not gender biased.

Research Question 5

Is there any difference in the mean achievement scores of male and female students taught chemistry using problem-based instructional strategy?

Table 14: Mean pre-test and posttest achievement scores of male and female students taught chemistry using problem-based instructional strategy

Gender	N	Pretest		Posttest		Mean
		Mean	SD	Mean	SD	Gain
Male	49	20.61	7.33	53.67	11.89	33.06
Female	63	19.60	7.20	48.73	12.48	29.13

In table 14, the male posttest mean score is 53.67 with a pretest mean score of 20.61 and mean gain of 33.06 and the females had a posttest score of 48.73 with pretest mean score of 19.60 and mean gain of 29.13 when exposed to problem-based instructional strategy. The overall mean difference between the genders is 3.93. This showed that the male students scored higher than their female counterparts.

Hypothesis 5

There is no significant difference between the mean achievement scores of male and female students taught chemistry using problem-based instructional strategy?

Table 15: Summary of independent t-test comparison of posttest mean achievement scores of male and female students taught chemistry using problem-based instructional strategy

Gender	N	$\bar{x}$	SD	DF	t-cal.	t-cri.	Sig. (2-tailed)	Decision
Male	49	53.67	11.89					
				110	2.12	1.98	0.04	Significant
Female	63	48.73	12.48					

Table 15 shows that there was a significant difference between the mean achievement scores of male and female students taught chemistry using problem-based instructional strategy, T = 2.123, P(0.04) < 0.05. Thus, the null hypothesis was rejected since t-calculated value (2.12) is greater than t-critical value (1.98). Therefore, there is a significant difference between the mean achievement scores of male and female students taught chemistry using problem-based instructional strategy in favour of male. The treatment therefore is gender biased.

Research Question 6

Is there any interaction effect between teaching methods and gender on achievement in chemistry?

Table 16: Mean and standard deviation on interaction effect between teaching methods and gender

Methods		Problem-based			Discovery-based			Lecture	
	N	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Pretest									
Male	49	20.61	7.33	46	21.09	7.30	40	20.75	7.56
Female	63	19.60	7.20	57	20.35	7.06	61	20.08	7.39
Differences		**1.01**	**0.13**		**0.74**	**0.24**		**0.67**	**0.17**
Posttest									
Male	49	53.67	11.89	46	39.57	11.39	40	38.12	8.37
Female	63	48.73	12.48	57	43.68	13.71	61	38.93	8.32
Differences		**4.94**	**-0.59**		**-4.11**	**-2.71**		**-0.81**	**0.05**

Table 16 shows a mean achievement score of 53.67 and 39.57 for male students who were taught with problem-based and discovery-based instructional strategies (experimental groups), while their female counterparts had a mean achievement scores of 48.73 and 43.68 respectively. Male students who were taught with lecture method had a mean achievement score of 38.12 while their female counterparts had a mean achievement score of 38.93. The results do not suggest ordinal interaction effect between teaching methods and gender on students' achievement in chemistry. This was because at all the levels of gender, the mean achievement scores were higher for students in the experimental groups. However, the results also suggest disordinal interaction effect between discovery-based instructional strategy and gender. Table 16 indicated a pretest mean achievement score of 21.09 and a posttest mean achievement score of 39.57 for male, while their female counterpart recorded a pretest mean achievement score of 20.35 and a posttest mean achievement score of 43.68. This showed that the female students performed better than their male counterparts when taught using discovery-based instructional strategy.

Hypothesis 6

There is no significant interaction effect between gender and method on achievement.

Table 17: ANCOVA summary of interaction effect of gender and teaching methods on achievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10232.264[a]	6	1705.377	13.404	.000
Intercept	77078.368	1	77078.368	605.826	.000
Pre	381.299	1	381.299	2.997	.084
Meth	9080.411	2	4540.205	35.685	.000
Gender	1.243	1	1.243	.010	.921
Meth * Gender	1130.827	2	565.414	4.444	.013
Error	39313.622	309	127.229		
Total	661850.000	316			
Corrected Total	49545.886	315			

a. R Squared = .207 (Adjusted R Squared = .191)

Table 17 shows that there was a significant interaction effect between gender and teaching methods as measured by the students' mean achievement scores in chemistry, $F(2, 309) = 4.444$, $P(0.013) < 0.05$. Therefore, the null hypothesis was rejected. Thus, there is a significant interaction effect between gender and teaching methods as measured by the mean scores in Chemistry Achievement Test (CAT). This implies that the students' achievement scores relative to the teaching methods is influenced by gender.

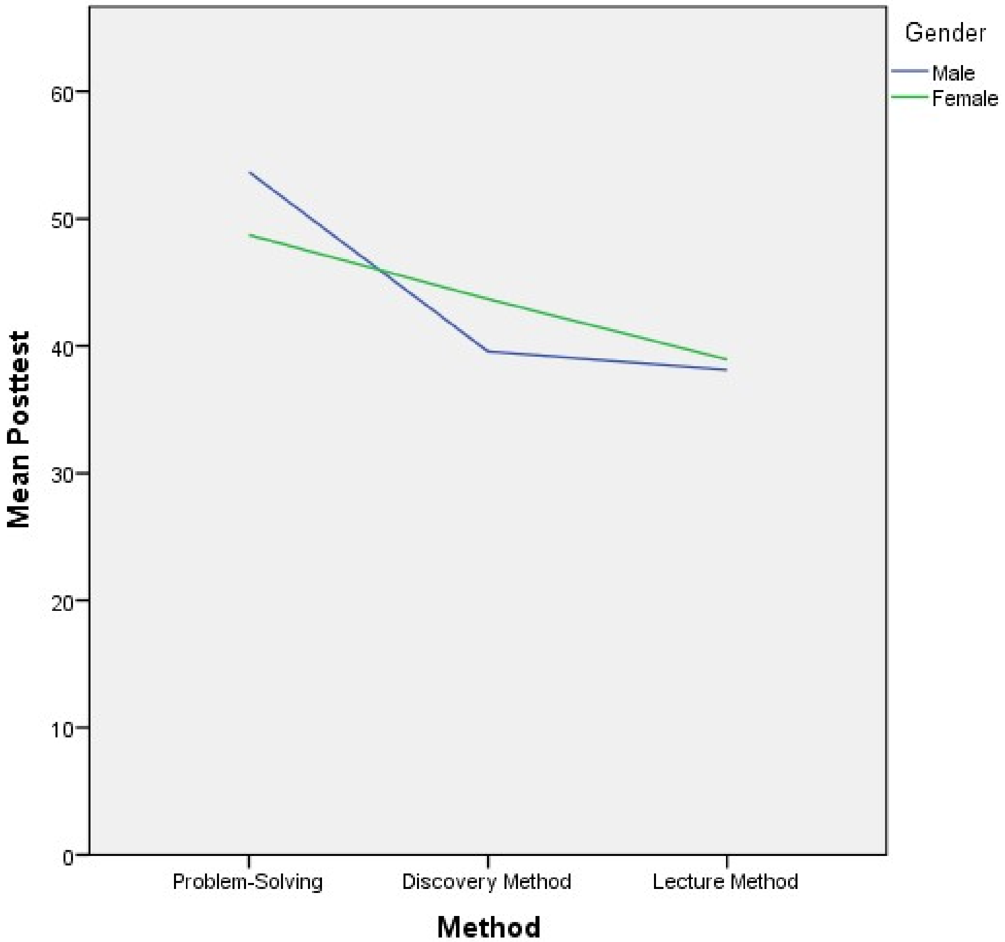

Figure 1: Plot of the interaction between gender and teaching methods indicating a significant interaction effect

The plot of the interaction effect between gender and teaching method is significant and disordinal. This shows that the teaching method has different effects on different conditions, for example, the effect of the teaching method changed when gender is put into consideration. In this study, female students with a mean achievement pretest score of 20.35 outperformed their male counterparts with a pretest mean achievement score of 21.09 by recording a posttest mean achievement score of 43.68 as compared to their male counter with a posttest score of 39.57 after treatment with the use of discovery-based instructional strategy.

Research Question 7

Is there any interaction effect between teaching methods and school location on achievement?

Table 18: Mean and standard deviation on interaction effect between teaching methods and school location

Methods	Problem-based			Discovery-based			Lecture		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Pretest									
Urban	60	20.25	6.85	53	19.62	6.99	51	20.88	7.40
Rural	52	19.81	7.73	50	21.80	7.19	50	19.80	7.49
Differences		**0.44**	**-0.88**		**-2.18**	**-0.20**		**1.08**	**-0.09**
Posttest									
Urban	60	52.75	10.59	53	44.06	14.25	51	37.94	8.14
Rural	52	48.75	14.03	50	39.50	10.50	50	39.30	8.51
Differences		**4.00**	**-3.44**		**4.56**	**3.75**		**-1.36**	**-0.37**

Table 18 shows a mean achievement score of 52.75 and 44.06 for urban students who were taught with problem-based and discovery-based instructional strategies (experimental groups), while their rural counterparts had a mean achievement scores of 48.75 and 39.50 respectively. Urban students who were taught with lecture method had a mean achievement score of 37.94 while their rural counterparts had a mean achievement score of 39.30. The results do not suggest ordinal interaction effect between teaching methods and school location on students' achievement in chemistry. This was because at all the levels of location, the mean achievement scores were higher for students in the experimental groups.

Hypothesis 7

There is no significant interaction effect between method and school location on achievement?

Table 19: Summary of interaction effect between teaching methods and school location on achievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10056.235[a]	6	1676.039	13.115	.000
Intercept	75827.414	1	75827.414	593.337	.000
Pre	300.002	1	300.002	2.347	.127
Meth	8414.100	2	4207.050	32.919	.000
Location	441.825	1	441.825	3.457	.064
Meth * Location	493.293	2	246.647	1.930	.147
Error	39489.651	309	127.798		
Total	661850.000	316			
Corrected Total	49545.886	315			

a. R Squared = .203 (Adjusted R Squared = .187)

Table 19 shows that there was no significant interaction effect between teaching methods and school location as measured by the students' mean achievement scores, $F(2, 309) = 1.930$, $P(0.147) > 0.05$. Therefore, the null hypothesis was not rejected. Thus, there is no significant interaction effect between teaching methods and school locations as measured by the students' mean achievement scores in Chemistry Achievement Scores (CAT).

Research Question 8

Is there any interaction effect among teaching methods, gender, and school location on achievement in chemistry?

Table 20: Mean and standard deviation on interaction effect among teaching methods, gender and school location on achievement

Methods		**Problem-based**			**Discovery-based**			**Lecture**	
	N	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Pretest									
Male	49	20.61	7.33	46	21.09	7.30	40	20.75	7.56
Female	63	19.60	7.20	57	20.35	7.06	61	20.08	7.39
Differences		**1.01**	**0.13**		**0.74**	**0.24**		**0.67**	**0.17**
Urban	60	20.25	6.85	53	19.62	6.99	51	20.88	7.40
Rural	52	19.81	7.73	50	21.80	7.19	50	19.80	7.49
Differences		**0.44**	**-0.88**		**-2.18**	**-0.20**		**1.08**	**-0.09**
Posttest									
Male	49	53.67	11.89	46	39.57	11.39	40	38.12	8.37
Female	63	48.73	12.48	57	43.68	13.71	61	38.93	8.32
Differences		**4.94**	**-0.59**		**-4.11**	**-2.71**		**-0.81**	**0.05**
Urban	60	52.75	10.59	53	44.06	14.25	51	37.94	8.14
Rural	52	48.75	14.03	50	39.50	10.50	50	39.30	8.51
Differences		**4.00**	**-3.44**		**4.56**	**3.75**		**-1.36**	**-0.37**

Table 20 shows a mean achievement score of 53.67 and 39.57 for male students who were taught with problem-based and discovery-based instructional strategies (experimental groups), while their female counterparts had a mean achievement scores of 48.73 and 43.68 respectively. Male students who were taught with lecture method had a mean achievement score of 38.12 while their female counterparts had a mean achievement score of 38.93.

Table 20 shows a mean achievement score of 52.75 and 44.06 for urban students who were taught with problem-based and discovery-based instructional strategies (experimental groups), while their rural counterparts had a mean achievement scores of 48.75 and 39.50 respectively. Urban students who were taught with lecture method had a mean achievement score of 37.94 while their rural counterparts had a mean achievement score of 39.30. The results do not suggest ordinal interaction effect among teaching methods, gender and school location on students' achievement in chemistry. This was because at all the levels of gender and school location, the mean achievement scores were higher for students in the experimental groups.

Hypothesis 8

There is no significant interaction effect among gender, method and school location on achievement chemistry.

Table 21: Summary of interaction effect among teaching methods, gender and school location on achievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11499.636[a]	12	958.303	7.632	.000
Intercept	75374.888	1	75374.888	600.285	.000
Pre	314.969	1	314.969	2.508	.114
Gender	10.560	1	10.560	.084	.772
Meth	8314.243	2	4157.122	33.107	.000
Location	453.270	1	453.270	3.610	.058
Meth * Gender	1130.827	2	565.414	4.444	.013
Gender * Location	102.744	1	102.744	.818	.366
Meth * Location	493.293	2	246.647	1.930	.147
Gender * Meth * Location	78.331	2	39.166	.312	.732
Error	38046.250	303	125.565		
Total	661850.000	316			
Corrected Total	49545.886	315			

a. R Squared = .232 (Adjusted R Squared = .202)

Table 21 shows that there was no significant interaction effect among teaching methods, gender and school location as measured by the students' mean achievement scores, $F(2, 303) = 0.312$, $P(0.732) > 0.05$. Therefore, the null hypothesis was not rejected. Thus, there is no significant interaction effect among teaching methods, gender and school locations as measured by the students' mean achievement scores in Chemistry Achievement Scores (CAT).

Discussion of Results

The first finding of this study revealed that there was a significant difference in the mean achievement scores among the experimental and control groups. The variations in achievement scores among the groups may be due to the variation in the teaching strategies adopted in each of the groups' and subjects' comprehension of the methods of instruction. These may again have translated into influencing subject's scores in the achievement test. The post hoc analysis which indicated that all the students taught with problem-based and discovery-based instructional strategies outscored those taught with lecture method suggests that the students in the experimental groups may have been more active in the learning process than those in the lecture group and thus have contributed to their higher achievement scores. This is hinged on the fact that you learn better by doing (Ajaja, 2013). The low achievement scores as found among the students taught with lecture method may not be unconnected with the transmission approach involved, where the teachers pass over their knowledge to their pupils. Bennett (2003) noted that the transmission view implies that pupil's role in the learning process is largely passive, and that a pupil's mind is what is some-times called a "tabula rasa".

The significant higher achievement of students taught with problem-based and discovery-based instructional strategies over those taught with lecture method as found in this study is consistent with the findings of earlier researchers on this same subject matter. For example, studies by Anyafulude (2014), Keislar (2008) and Mayer (2003) established the relative efficacy of problem-based and discovery-based instructional strategies in fostering students' achievement in chemistry relative to the lecture method.

On the noticed significant higher achievement of students taught with problem-based instructional strategy over those taught with discovery-based instructional strategy, the limitations ascribed to discovery-based instructional strategy may be the possible explanation for the lower score. Anyafulude (2014) stated that while the discovery-based instructional strategy suggest that the learner is not provided with the target information or conceptual understanding and must find it independently or collectively in groups and only with the provided materials, the problem-based instructional strategy avails students of the opportunity to carefully select and design problems that demand from the learner acquisition of critical knowledge, problem solving proficiency, self directed learning strategies and team participation skills (Maloney, 2004). Problem-based strategy reduces teacher's instruction where learners are seen as active listeners and passively involved in classroom activities as in the case of conventional method. More so, problem-based strategy as an example of constructivist learning strategy poses significant contextualized real world situation and provide resources, guidance and instruction to learning as they develop content knowledge and problem solving skills (Yager, 2001). These limitations may have frustrated the low achievers particularly and resulted in their lower achievement scores to produce the lower mean score for the discovery-based instructional strategy group.

Another finding of this study revealed that the urban students achieved higher than the rural students with a mean difference of 6.74 which was found to be insignificant. In other words, there is no significant difference between the mean achievement scores of students taught chemistry using discovery-based instructional strategy in urban and rural areas. The score variation is higher in the urban students, although it increased among the two locations after treatment with discovery-based instructional strategy. This finding is in contrasts with the views of Ozioko (2015) and Okoro (2011) who concluded that school location had a significant effect on the students' achievement in foods and nutrition. The explanation for the observed non-significant difference in achievement of urban and rural students is that the there is a bridge in the gap that existed between the surrounding of rural schools which used to have inadequate materials for teaching as compare to urban schools which have lots of fascinating and stimulating materials for teaching as a result of school facilities rehabilitation by government and other stake holders in education.

In this study, school location is found to have no significant effect on the students' achievement in chemistry. The result revealed that the mean achievement scores of students taught chemistry using problem-based instructional strategy in urban and rural area does not significantly differs. This can be attributed to improved school facilities in rural schools which have help to close the gap that existed between urban and schools in terms of school facilities and stimulating environment. This finding corroborates with the view of Nbina and Joseph (2011) who reported that no significant difference were observed in the posttest mean achievement scores of urban and rural students when taught using problem-based instructional strategy.

The study also revealed that the female students achieve higher than the male students when taught chemistry with discovery-based instructional strategy with a mean difference of -2.32 which was found to be insignificant. This finding is in line with the findings of Ozioko (2015), Okoro (2011), Obikese (2007), Maduabum (1995). They discovered in their study that there was no significant gender difference in the post test achievement of the experimental group taught with the expository and guided discovery method in Biology, notwithstanding the difference that existed in the pre-test result in favour of the male. These indicated that with the use of any good teaching method, male and female students will achieve equally (Ozioko, 2015).

Another finding of this study revealed that the mean achievement scores of male students was found to be significantly greater than their female counterparts when taught chemistry using problem-based instructional strategy. The observed male superiority in achievement is in line with the findings of studies conducted by Nwagwu (1999), Ibeme (2000) and Hutt (2002) which found out that male students achieved significantly higher than female students in sciences and mathematics. The finding of this study did not deviate from the already established pattern of male superiority in chemistry achievement. However, the finding of this study is in contrast with the finding of Anyafulude (2014) who observed the problem-based instructional strategy significantly enhanced female students' performance then male counterparts.

The study also revealed a significant interaction effect between teaching methods and gender as measured by the mean achievement scores in chemistry achievement test. One possible explanation that could suffice is that the students' interest may have been aroused and sustained in a particular gender than the other through the discovery-based instructional strategy. Discovery-based instructional strategy influenced the mean achievement scores of female students than their male counterparts. This finding is in agreement with the finding of Dania (2014) who observed a significant interaction effect of treatment and gender on students' academic achievement in social studies.

The study further revealed no significant interaction effect between teaching methods and school locations as measured by the students' mean achievement scores in Chemistry Achievement Scores (CAT). This finding is in line with that of Momoh (2001) who found no significant interaction effect of school location and instructional treatment.

The study finally revealed no significant interaction effect among teaching methods, gender and school location on achievement in chemistry. This finding corroborates with the view of Nekang (2013) and Momoh (2001) who found no interaction effect among teaching methods, gender and school location on achievement.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMNDATIONS

This chapter presents summary of the study, the conclusions from the study, contribution of the research to knowledge, the recommendations made in the light of the findings of the study and the suggestions for further studies.

Summary of the Research

The study focused on the effects of problem-based and discovery-based instructional strategies on students' academic achievement in chemistry in Delta Central Senatorial District of Delta State. Eight research questions and eight hypotheses were raised and formulated respectively to guide the study. The design of the study is quasi-experimental design, specifically non-equivalent control group, pretest, posttest design. Population of the study was Senior Secondary two (SS II) chemistry students. There are 8,945 SS II chemistry students in the 179 public secondary schools in Delta Central Senatorial District. A sample of 316 SS II chemistry students from six secondary schools in Delta Central Senatorial District were used for this study. The instruments used in the study was a chemistry achievement test (CAT) drawn from a six weeks instructional units on nitrogen and its compounds designed by the researcher which was validated by two lecturers; one science educator in chemistry and an expert in measurement and evaluation in Delta State University Abraka and one experienced chemistry teacher drawn from a school in Warri South Local Government Area of Delta. The reliability of the CAT was established using the kudder-Richardson formula 21. This was done by administering the CAT to thirty chemistry students outside the area of the study and computing the reliability index. The reliability coefficient of the instrument was found to be 0.83.

The treatment involved exposing the students in the experimental groups to the chemistry concept "Nitrogen and its compounds" with the use of problem-based and discovery-based instructional strategies and the control group with lecture method. Pretests were administered before the treatment and posttest thereafter. The scores obtained were collated and analyzed using descriptive statistics, independent sample t-test, analysis of variance (ANOVA) and analysis of covariance (ANCOVA). The major findings of the study revealed that:

1. There was a significant difference in the mean achievement scores among students taught chemistry using problem-based, discovery-based and lecture method. The post-hoc analysis indicated that students taught chemistry with the use of problem-based instructional strategy came out top followed by students taught chemistry with discovery-based instructional strategy and lecture method respectively.
2. There was no significant difference between the mean achievement scores of students taught chemistry using discovery-based instructional strategy in urban and rural areas.
3. There was no significant difference between the mean achievement scores of students taught chemistry using problem-based instructional strategy in urban and rural area.

4. There was no significant difference between the mean achievement scores of male and female students taught chemistry using discovery-based instructional strategy.
5. There was a significant difference between the mean achievement scores of male and female students taught chemistry using problem-based instructional strategy in favour of male.
6. There was a significant interaction effect between teaching methods and gender as measured by the students' mean achievement scores in chemistry achievement test (CAT).
7. There was no significant interaction effect between teaching methods and school locations as measured by the students' mean achievement scores in chemistry achievement scores (CAT).
8. There was no significant interaction effect among teaching methods, gender and school location on achievement in chemistry as measured by the students' mean achievement scores in chemistry achievement scores (CAT).

Conclusion

The following conclusions were drawn based on the major findings of this study:

1. Since there was a significant difference in the mean achievement scores among students taught chemistry with problem-based, discovery-based instructional strategies and lecture method in favour of problem-based group followed by discovery-based and lecture groups respectively, it is therefore concluded that

problem-based and discovery-based instructional strategies enhance students understanding of chemistry concepts more as compare to lecture method.

2. Since there was no significant difference between the mean achievement scores of students taught chemistry with problem-based and discovery-based instructional strategies in urban and rural areas, it is therefore concluded that problem-based and discovery-based instructional strategies enhanced the mean achievement scores of students in urban and rural area.

3. Since there was no significant difference between the mean achievement scores of male and female students taught chemistry using discovery-based instructional strategy, hence it is therefore concluded that discovery-based instructional strategy enhanced the mean achievement scores of both male and female students.

4. Since male students significantly out-performed their male counter-part when taught chemistry using problem-based instructional strategy, it is therefore concluded that problem-based instructional strategy enhanced the mean achievement scores of male students more as compare to their female counterpart.

5. Since there was a significant interaction effect between teaching methods and gender on achievement in chemistry, it is therefore concluded that discovery-based instructional strategy interact with female students mean achievement scores in chemistry. Discovery-based instructional strategy influence female students mean achievement scores.

6. Since there was no significant interaction effect between teaching methods and school location, it is therefore concluded that problem-based and discovery-based instructional strategy did not combine with school location to influence students mean achievement scores.

7. Since there was no significant interaction effect among teaching methods, gender and school location on achievement in chemistry, it is therefore concluded that problem-based and discovery-based instructional strategies did not combine with gender and school location to influence students mean achievement scores in chemistry.

Recommendations

In the light of the findings of the study, the following recommendations are made:

1. Chemistry teachers should adopt the use of problem-based and discovery-based instructional strategies in the teaching of chemistry at the secondary school level. These instructional strategies will ensure students active involvement, self discovery of knowledge as well as interaction with the learning materials during the teaching-learning process.

2. Special training on the effective implementation of problem-based and discovery-based instructional strategies should always be organized for teachers and students by the government, so as to help them become competent in the use of these teaching strategies in the teaching and learning process.

3. Workshops and seminars should be organized for teachers and students to keep them abreast of other innovative active teaching strategies to enhance easy implementation in classroom teaching.

Contributions to Knowledge

This study on the effects of problem-based and discovery-based instructional strategies has contributed the following to knowledge.

The study established that problem-based and discovery-based instructional strategies significantly improve students' achievement in chemistry.

The study also established that the effects of problem-based and discovery-based instructional strategies on chemistry achievement are not location biased.

The study also confirmed that male and female chemistry students exposed to discovery-based instructional strategy perform equally.

The study also established that problem-based instructional strategy improves the academic achievement of male students more, compared to their female counterparts.

The study also established that there is a significant interaction effect between discovery-based instructional strategy and female students' achievement in chemistry.

The study finally established that there is no significant interaction effect among teaching methods, gender and school location.

Suggestions for Further Research

The following were suggestions for further research:

1. A research should be carried out on the effects of problem-based and discovery-based instructional strategies on students' achievement, attitude and interest in chemistry.
2. Research studies on the effects of problem-based, discovery-based instructional strategies and sex on students' achievement and interest in chemistry is suggested.
3. Research studies on effects of effects of problem-based, discovery-based and location on students' achievement and interest in chemistry is also suggested.

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APPENDICES

APPENDIX A

LESSON PLAN FOR PROBLEM-BASED INTRUCTIONAL STRATEGY

Lesson 1

Subject : Chemistry
Week : 5
Class : SSII
Age : 15+
Duration : 45 minutes
Topic : Nitrogen and its Compounds

Specific Objectives: By the end of the class, the students should be able to:

1. Describe the electronic structure and occurrence of nitrogen
2. Describe the laboratory and chemical method of preparing nitrogen

Instructional materials: New school Chemistry by Osei Yaw Ababio, chart of nitrogen and its compounds, sodium dioxonitre(III), ammonium chloride, heptaoxodichromate(VI), water, litmus paper, etc.

Instructional techniques: The teacher shall employ group discussion, group presentation, group exercise in delivering the content of the topic

Entry behaviour: It is expected that students are already able to state the properties of P-block elements.

Revision of previous lesson and attendance: The teacher reviews or presents a brief summary of the last lesson and asks the students the following questions to refresh their memory:

1. Give 2 uses of any oxide of sulphur
2. Give any 4 uses of tetraoxosulphate (VI) acid

CONTENT DEVELOPMENT:

Sub topics	Teacher activities	Student's activities	Instructional Strategy and skills
Step 1 Introduction Nitrogen	Teacher guides students to identify the problem (Occurrence and preparation of Nitrogen) and help them to link it with their previous knowledge The teacher then organizes the students in	Listen to teacher Follow the teachers'	Questioning, explanation

	groups of five and appoints group leaders The teacher further instructs the students to make sure they take down points during the lesson as each group shall be called upon to summarize any part of the lesson contents and answer the questions that follows	directives	
Step 2 Nitrogen	Teacher gives the students the following notes and ask them to discuss it among their groups Nitrogen which is in Group 5 of the Periodic Table has five valence electrons i.e has five electrons in the outermost shell. As a result, it achieves its stable octet structure by forming covalent bonds in its compounds. It slso forms the nitride ion, N^{3-}, in combinations with the very reactive metals of Group 1 and 2. Nitrogen shows oxidation states varying from -3 to +5 in its various compounds. Nitrogen gas exists in air as a diatomic molecule with triple covalent bonds between its atom. Nitrogen occurs chiefly as a free element in the air, making up about 78% by volume of the atmosphere. Free nitrogen in the air is important because it dilutes the oxygen to the point where combustion, respiration and oxidation of metals are reasonably slow. In the combined form, nitrogen occurs abundantly in the earth's crust as trioxonitrate(V) of sodium and calcium, as well as ammonium salt. Combined nitrogen is also found in organic matter such as proteins, urea and vitamin B compounds.	Students will discuss the notes, bring out the major points and summarize for presentation.	Explanation
Step 3 Laboratory preparation	The teacher will ask the various groups to use different textbooks, discuss and write about the laboratory and industrial preparation of	Students use their textbooks and research on the	Explanations and use of examples

<table>
<tr>
<td>of nitrogen</td>
<td>nitrogen.

The teacher asks the various group to present what they discovered after which he gives them the notes below

<u>Laboratory preparation of Nitrogen</u>

Since nitrogen makes up a large percentage of air, it can be obtained from air by removing the other constituents. For example, carbon(IV) oxide and oxygen can be removed by passing air through caustic soda and heated copper turnings respectively. However, the nitrogen obtained this way contains about 1% by volume of rare gases as impurities, and is denser than pure nitrogen.

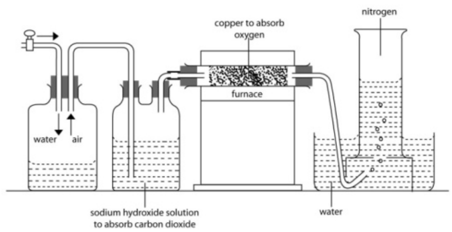

Fig. 1: Laboratory preparation of nitrogen from air

Nitrogen can also be produced by the following chemical methods:

From ammonium dioxonitrate(III): Pure nitrogen is usually obtained by thermal decomposition of ammonium dioxonitrate(III), NH_4NO_2. The dioxonitrate(III), however, is not heated directly as the reaction may get out of control and an explosion may occur. This because ammonium dioxonitrate(III) is unstable and decompose exothermically.

A mixture of sodium dioxonitrate(III) and and</td>
<td>laboratory and industrial preparation of nitrogen.

Each group present what they discovered from their groups. They now compare the teacher’s notes with theirs and add points which they missed.</td>
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	ammonium chloride in a ratio of 7:5 is heated to yield ammonium dioxonitrate(III), which in turn decomposes to produce nitrogen and steam. This procedure is safer than heating dioxonitrate(III) directly because ammonium dioxonitrate(III) is decoposed as fast as it is formed. **(a) $NaNO_2(aq) + NH_4CL(aq) \longrightarrow NH_4NO_2(aq) + NaCl$** **(b) $NH_4NO_2(aq) \longrightarrow N_2(g) + 2H_2O(l)$** **From ammonium heptaoxodichromate(VI):** When the heptapxpdichromate(VI), $(NH_4)_2Cr_2O_7$, is heated, it decomposes to yield nitrogen. **$(NH_4)_2Cr_2O_7(s) \longrightarrow N_2(g) + Cr_2O_3(s) + 4H_2O(l)$** **From ammonia:** Nitrogen is liberated when ammonia is oxidized by hot copper(II) oxide. **$2NH_3(g) + 3CuO(s) \longrightarrow 3Cu(s) + 3H_2O(g) + N_2(g)$** **From dinitrogen(I) oxide:** when dinitrogen(I) oxide is passed over red-hot copper, the gas is reduced to nitrogen. **$N_2O(g) + Cu(s) \longrightarrow CuO(S) + N_2(g)$**		
Step 4 Summary	Teacher calls on various group members to summarize the different contents of the topic taught	Comes out in groups to summarize points	Group presentation
Step 5 Evaluation	Teacher asks the following questions to be answered by each group: 1. Describe the electronic structure of	Answers the questions	Instructional closure and questioning

	nitrogen 2. Describe the occurrence and preparation of nitrogen in the laboratory 3. Describe two chemical method of producing nitrogen		
Step 6 Assignment	Each group will be required to make a presentation in the next class of industrial preparation of nitrogen		

Lesson 2

Subject : Chemistry

Week : 6

Class : SII

Age : 15+

Duration : 45 minutes

Topic : Industrial preparation of Nitrogen

**Specific Objectives : **By the end of the class, the students should be able to:

1. Describe in details the industrial preparation of nitrogen

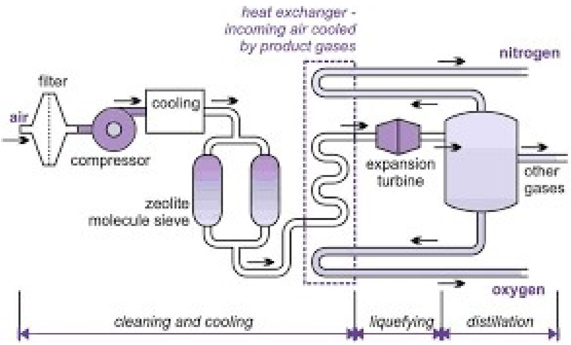
Instructional Materials: New school Chemistry by Osei Yaw Ababio, chart of nitrogen and its compounds, thermometer, magnesium, iron, calcium, gas cylinder, water, litmus paper.

Instructional techniques: The teacher shall employ group presentation.

Entry behaviour: It is expected that students are already able to describe nitrogen and its laboratory method of preparation

CONTENT DEVELOPMENT:

Sub topics	**Teacher activities**	**Student's activities**	**Instructional Strategy and skills**
Step 1 Introduction Nitrogen	Teacher guides students to identify the problem (Occurrence and preparation of Nitrogen) and help them to link it with their previous knowledge The teacher then organizes the students in groups of five and appoints group leaders The teacher further instructs the students to make sure they take down points during the lesson as each group shall be called upon to summarize any part of the lesson contents and answer the questions that follows	Listen to teacher Follow the teachers' directives	Questioning, explanation

Step 2 Industrial preparation of nitrogen	Teacher gives the students the following notes and ask them to discuss it among their groups **<u>Industrial Preparation of Nitrogen</u>** Industrially, nitrogen is prepared by the fractional distillation of liquid of liquid air. Air, from which carbon(IV) oxide has been removed, is liquefied by subjecting it to successive compression and cooling processes. Upon distillation, nitrogen gas is evolved first at -196°C (at s.p.) and is separated from oxygen which boils at -183°C (at s.p.). Nitrogen is stored in steel cylinders and sold as liquid nitrogen or as the compressed gas.  **Fig. 2: Industrial preparation of nitrogen by fractional distillation of liquid air**	Students will discuss the notes, bring out the major points and summarize for presentation	Explanation and use of examples
Step 3 Summary	Teacher calls on various group members to summarize the different contents of the topic taught	Comes out in groups to summarize points	Group presentation
Step 4 Evaluation	Teacher asks the following questions to be answered by each group: 1. Describe the industrial preparation of nitrogen indicating the various	Answers the questions	Instructional closure and questioning

	functions of the reagents involved		
Step 5 Assignment	Each group will be required to make a presentation in the next class of physical and chemical properties of nitrogen, uses of nitrogen.		

Lesson 3

Subject : Chemistry

Week : 7

Class : SII

Age : 15+

Duration : 45 minutes

Topic : Physical, chemical properties and uses of Nitrogen

Specific Objectives : By the end of the class, the students should be able to:

2. Enumerate with equations where necessary at least two chemical and physical properties of nitrogen.
3. Highlight three uses of nitrogen

Instructional Materials: New school Chemistry by Osei Yaw Ababio, chart of nitrogen and its compounds, thermometer, magnesium, iron, calcium, gas cylinder, water, litmus paper.

Instructional techniques: The teacher shall employ group presentation.

Entry behaviour: It is expected that students are already able to describe nitrogen and its method of preparation

CONTENT DEVELOPMENT:

Sub topics	Teacher activities	Student's activities	Instructional Strategy and skills
Step 1 Revision/ Introduction	Teachers refreshes the students' memory on the previous lesson and asks the following questions 1. Describe the electronic structure of nitrogen. 2. Describe the occurrence and preparation of nitrogen in the laboratory 3. Describe two chemical method of preparing nitrogen. Teacher guides students to identify the problem (properties and uses of Nitrogen).	Answers question	Revision
Step 2	The teacher guides the students through a	Take down	Group

Group presentation On Physical and chemical properties of nitrogen	group presentation on the properties and uses of nitrogen Teacher also guides an intergroup discussion of the presented topics Teacher summaries the presentations as follows: **<u>Physical properties of Nitrogen</u>** 1. Nitrogen is a colourless, odourless and tasteless gas. 2. Pure nitrogen is slightly lighter than air 3. It is only slightly soluble in water. Two volumes of the gas dissolve 100 volumes of water at room temperature. 4. The melting point of nitrogen is -210^{o}C and its boiling point is -196^{o}C. These low temperatures are due to the weak van der Waals forces that exist between the nitrogen molecules in the solid and liquid states. **Chemical properties of Nitrogen** Nitrogen gas exists in air as a diatomic molecule with triple covalent bonds between its atoms. The high bond energy of the triple bond (946 $KJmol^{-1}$) makes the bond very stable and accounts for the unreactive nature of nitrogen under ordinary conditions. However, at very high temperatures and pressures, nitrogen combines directly with hydrogen, oxygen and certain metals. **With metals:** Nitrogen combines directly with very electropositive metals, e.g. magnesium, calcium, aluminium and iron,	notes as they listen to the each other, ask questions	presentation and activities

	to form nitrides. For example, red-hot magnesium combines directly with nitrogen to produce magnesium nitride. The nitride is readily hydrolyzed when warmed with water to give ammonia gas. **(a) $Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$** **(b) $Mg_3N_2(s) + 6H_2O(l) \xrightarrow{warm} 3Mg(OH)_2 + 2NH_3(g)$** **With non-metals:** Nitrogen combines reversibly with hydrogen to produce ammonia. It combines directly with oxygen at very high temperatures (about 2000°C) or in the presence of a high voltage electric spark to form small amounts of nitrogen(II) oxide. In nature, this reaction occurs in the atmosphere when lightning flashes. **$N_2(g) + O_2(g) \longrightarrow 2NO(g)$**		
Step 3 Uses of nitrogen	Teacher asks each group to write out three uses of sulphur they can think of **Uses of Nitrogen** 1. Nitrogen is used in the industrial manufacture of ammonia, cyanide and carbamide (an important fertilizer). 2. Liquid nitrogen is used as a cooling agent. 3. Due to its inert nature, nitrogen is used; • As a carrier gas in gas chromatography; • In providing an inert atmosphere for certain industrial processes involving easily oxidizable chemicals, e.g. in making electronic components such as	Each group discuss and write out three uses of nitrogen	Group discussion and stimulus variation

	transistors, and in the annealing of metals; • As a preservative to prevent rancidity (due to the oxidation of fats) in packaged foods.		
Step 4 Summary	Group are allowed to discuss, prepare and present summaries	Presentation	Instructional closure
Step 5 Evaluation	Teacher writes the following questions on the board for groups to put heads together and put forward a group answer through the group leaders 1. Outlist 4 physical properties of nitrogen. 2. List with equations 2 chemical properties of nitrogen. 3. Mention 3 uses of nitrogen. Assignment on the compounds of nitrogen are then given to each group	Answers the questions	questioning

Lesson 4

Subject : Chemistry
Week : 8
Class : SS1I
Age : 15+
Duration : 45 minutes
Topic : Compounds of Nitrogen

Specific Objectives: By the end of the lesson, the students should be able to:

1. Give examples of some important compònds of nitrogen
2. Describe the laboratory preparation of ammonia (NH_3)

Instructional materials: New school Chemistry by Osei Yaw Ababio, chart showing the preparation of ammonia from from ammonium chloride, calcium hydroxide solution, water, U-tube, fractionating flask etc.

Instructional techniques:The teacher shall employ group presentations and teacher summary

Entry behaviour: it is expected that students are already able to describe nitrogen.

CONTENT DEVELOPMENT:

Sub topics	Teacher activities	Student's activities	Instructional Strategy and skills
Step 1 Revision of previous lesson/ Introduction	The teachers reviews or presents a brief summary of the last lesson and ask the students the following questions to refresh their memory: 1. Describe the occurrence and preparation of nitrogen in the laboratory and industry. 2. Outline 4 physical properties of nitrogen 3. List with equations 2 chemical properties of nitrogen 4. Mention 3 uses of Nitrogen **Compounds of Nitrogen** Some of the important compounds of nitrogen are ammonia and ammonium	Answers questions Take down notes Students attempt to answer the question	Revision of previous lesson Set induction

	salts such as ammonium chloride (NH_4Cl), ammonium tetraoxosulphate(VI) ($(NH_4)_2SO_4$), ammonium trioxonitrate(V) (NH_4NO_3) and ammonium trioxocarbonate(IV) ($(NH_4)_2CO_3$).		Explanations
Step 2 Group presentation on Ammonia	The teacher guides the students through a group presentation on **Ammonia** Teacher also guides an intergroup discussion of the presented topics Teacher summaries the presentations as follows: Ammonia is a hydride of nitrogen. It is a very important chemical in industry. In nature, ammonia is produced when nitrogenous matter decays in the absence of air. The decomposition may be brought about by heat or putrefying bacteria. As a result, small traces of ammonia may be present in the air. However, because of its great solubility in water, it rapidly dissolves in rain water and finds its way into the soil where it may be converted into other compounds. **Laboratory preparation of NH_3** In the laboratory, ammonia is prepared by heating any ammonium salt with no-volatile base. Usually, ammonium chloride and calcium hydroxide is chosen because it is cheap and not deliquescent like caustic alkalis. Since both the reactants are solids, they should be thoroughly ground to provide the maximum surface area for reaction.	Students discuss and prepare for group presentation They listen to each group and ask questions	Group activities and presentation

	$Ca(OH)_2(s) + 2NH_4Cl(s) \rightarrow CaCl_2(s) + 2H_2O(l) + 2NH_3(g)$ The usual drying agents like conc. Tetraoxosulphate(VI) acid and fused calcium chloride are not suitable for drying ammonia because they react with the gas as follows: **$2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(s)$** **$4NH_3(g) + CaCl_2(s) \rightarrow CaCl_2.4NH_3(s)$**		
Step 3 Summary	Group are allowed to discuss, prepare and present summaries of presentations by other groups	Presentation And group activities	Instructional closure
Step 4 Evaluation	Teacher writes the following questions on the board for groups to put heads together and put forward a group answer through the group leader or any other member of the group 1. Give examples of some important compounds of nitrogen 2. Describe the laboratory preparation of NH_3 Assignment on the compounds of nitrogen are then given to each group	Answers the questions	questioning

Lesson 5

Subject	: Chemistry
Week	: 9
Class	: SS1I
Age	: 15+
Duration	: 45 minutes
Topic	: Compounds of Nitrogen

Specific Objectives: By the end of the lesson, the students should be able to:

1. Describe the industrial preparation of Ammonia
2. List two reagents and their function used in the preparation of ammonia

Instructional materials: New school Chemistry by Osei Yaw Ababio, chart showing the preparation of ammonia from from ammonium chloride and Haber process; calcium hydroxide solution, water, U-tube, fractionating flask etc.

Instructional techniques:The teacher shall employ group presentations and teacher summary

Entry behaviour: it is expected that students are already able to describe nitrogen.

CONTENT DEVELOPMENT:

Sub topics	Teacher activities	Student's activities	Instructional Strategy and skills
Step 1 Revision of previous lesson/ Introduction	The teachers reviews or presents a brief summary of the last lesson and ask the students the following questions to refresh their memory: 5. Describe the occurrence and preparation of nitrogen in the laboratory and industry. 6. Outline 4 physical properties of nitrogen 7. List with equations 2 chemical properties of nitrogen 8. Mention 3 uses of Nitrogen	Answers questions Take down notes Students attempt to answer the question	Revision of previous lesson Set induction

			Explanations
Step 2 **Group** presentation on Ammonia	The teacher guides the students through a group presentation on industrial preparation of ammonia Teacher also guides an intergroup discussion of the presented topics Teacher summaries the presentations as follows: **Industrial preparation NH_3 (Haber process)** Ammonia is manufactured from nitrogen and hydrogen by the Haber process. Since the direct combination between nitrogen and hydrogen is reversible, special conditions of reaction are necessary for the optimum yield of ammonia. Basically, the process involves mixing nitrogen and hydrogen in the volume ratio of 1:3 and passing the mixture; • Over finely divided iron (catalyst), • At a temperature of about 450°C, and • A pressure of about 200 atmospheres. The yield of ammonia is about 15% under these conditions. The ammonia is then liquefied by cooling, and the unused gases are re-circulated over the catalyst for further production of ammonia. **$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ + heat**	Students discuss and prepare for group presentation They listen to each group and ask questions	Group activities and presentation

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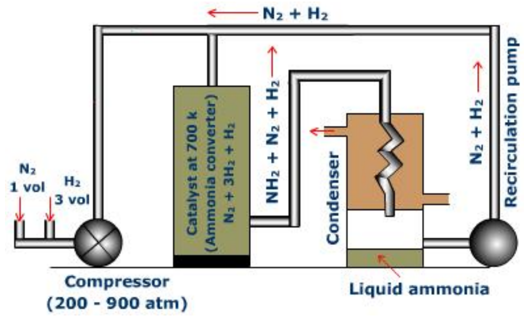
<tr><td></td><td>

Fig. 3: Preparation of Ammonia by the Haber Process</td><td></td><td></td></tr>
<tr><td>Step 3

Summary</td><td>Group are allowed to discuss, prepare and present summaries of presentations by other groups</td><td>Presentation And group activities</td><td>Instructional closure</td></tr>
<tr><td>Step 4

Evaluation</td><td>Teacher writes the following questions on the board for groups to put heads together and put forward a group answer through the group leader or any other member of the group

1. Describe the Haber process of preparing ammonia in the industry
2. List two reagents and the uses in the industrial preparation of ammonia

Assignment on the physical and chemical properties of ammonia are then given to each group</td><td>Answers the questions</td><td>questioning</td></tr>
</table>

Lesson 6

Subject : Chemistry
Week : 10
Class : SII
Age : 15+
Duration : 45 minutes
Topic : Physical properties and uses of HN_3

Specific Objectives: By the end of the class, the students should be able to:

1. States any 5 physical and chemical properties of NH_3
2. Give the uses of NH_3

Instructional Materials: New school Chemistry by Osei Yaw Ababio, chart of sulphur and its compounds, sulphuric acid, water, litmus paper.

Instructional techniques: The teacher shall employ group presentation

Entry behaviour: it is expected that students are already able to describe sulphure and its allotropes.

CONTENT DEVELOPMENT:

Sub topics	**Teacher activities**	**Student's activities**	**Instructional Strategy and skills**
Step 1 Revision/ Introduction	Teachers refreshes the students' memory on the previous lesson and asks the following questions: 1. Give examples of some important compounds of nitrogen 2. Describe the Haber process of the preparation of NH_3 →	Answers question	Revision
Step 2 **Group presentation on** **Physical and chemical properties of**	The teacher guides the students through a group presentation on the properties and uses of $\mathbf{NH_3}$ Teacher also guides an intergroup discussion of the presented topics Teacher summaries the presentations as	Students take down notes They listen to each group and ask	Group activities and presentation

NH_3	follows: **Physical Properties of NH_3** 1. Ammonia is a colourless gas with a characteristic choking smell 2. In large quantities, ammonia is poisonous because of its effect on the respiratory muscles. 3. It is an alkaline gas, changing moist red litmus paper blue. 4. It is about 1.7 times less dense than air. 5. Ammonia changes into liquid at -34.4^{o}C. It is easily liquefied into a colourless liquid at ordinary temperatures by compression, and is transported in this form. 6. Ammonia has a boiling point of -77.7^{o}C which is relatively high when compared with other similar compounds because of the presence of hydrogen bonding between its molecules. **Chemical properties of NH_3** **Reaction with Oxygen:** Ammonia does not burn in air, but it burns readily in oxygen with a greenish-yellow flame to form water vapour and nitrogen. $4NH_3(g) + 3O_2(g) \rightarrow 6H_2O(g) + 2N_2(g)$ **Ammonia as a reducing agent** **With copper(II) oxide:** Ammonia is not a strong reducing agent. However, it reduces heated copper(II) oxide to copper while it is itself oxidized to water and nitrogen. $3CuO(s) + 2NH_3(g) \rightarrow 4Cu(s) + 3H_2O(l) + N_2(g)$	questions	

	With chlorine: In excess, ammonia first reduces chlorine to produce hydrogen chloride and nitrogen. Then the hydrogen chloride reacts with the excess ammonia to produce white fumes of ammonium chloride. **(a)** $2NH_3(g) + Cl_2(g) \longrightarrow 6HCl(g) + N_2(g)$ **(b)** $6NH_3(g) + 6HCl(g) \longrightarrow 6NH_4Cl(s)$ **Reaction with Carbon(IV) oxide:** Ammonia reacts with carbon(IV) oxide at 150°C and a high pressure of 150atm to produce urea, an important organic compound. $2NH_3(g) + CO_2(g) \longrightarrow (NH_2)_2CO(s) + H_2O(l)$ **Thermal decomposition:** Ammonia is decomposed at temperatures above 500°C or prolonged sparking to yield nitrogen and hydrogen. **As a base:** Ammonia is a weak base because it can accept protons to form ammonium ions. It reacts with acids to form ammonium salts. $NH_3(g) + H^+(aq) \rightleftharpoons NH_4^+(aq)$ $2NH_3(g) + H_2SO_4(aq) \longrightarrow (NH_4)_2SO_4(s)$		

Step 3 **Uses of HN_3**	Teacher asks each group to write out three uses of H_2SO_4 they can think of **Uses of HN_3** 1. Aqueous ammonia is used in softening temporarily hard water. 2. Aqueous ammonia is also used in laundries as a solvent for removing grease and oil stains. 3. Liquid ammonia is used as a refrigerant, although it is now being replaced by less toxic and unreactive fluorocarbons. 4. Ammonia is used in the manufacture of trioxonitrate(V) acid and sodium trioxocarbonate(IV) by the Solvay process. 5. The most important use of ammonia is in the manufacture of nitrogenous fertilizers like ammonium tetraoxosulphate(VI), ammonium trioxonitrate(V), carbamide, and ammonium tetraoxosulphate(V).	Group discuss and write the uses of **HN_3**	Explanations, use of example and stimulus variation
Step 4 Summary	Teacher writes the following questions on the board for groups to put heads together and put forward a group answer through the group leaders	Listen to the teachers and ask questions	Instructional closure
Step 5 Evaluation	1. Outlist any 5 physical and chemical properties of NH_3 2. Mention any 8 uses of NH_3	Answers the questions	questioning

APPENDIX B

LESSON PLAN FOR DISCOVERY-BASED INSTRUCTIONAL STRATEGY

Lesson 1

Subject : Chemistry
Week : 5
Class : SSII
Age : 15+
Duration : 45 minutes
Topic : Nitrogen and its Compounds

Specific Objectives: By the end of the class, the students should be able to:

3. Describe the electronic structure and occurrence of nitrogen
4. Describe the laboratory and chemical method of preparing nitrogen

Instructional materials: New school Chemistry by Osei Yaw Ababio, chart of nitrogen and its compounds, sodium dioxonitre(III), ammonium chloride, heptaoxodichromate(VI), water, litmus paper, etc.

Instructional techniques: The teacher shall employ group discussion, group presentation, group exercise in delivering the content of the topic

Entry behaviour: It is expected that students are already able to state the properties of P-block elements.

Revision of previous lesson and attendance: The teacher reviews or presents a brief summary of the last lesson and asks the students the following questions to refresh their memory:

3. Give 2 uses of any oxide of sulphur
4. Give any 4 uses of tetraoxosulphate (VI) acid

CONTENT DEVELOPMENT:

Sub topics	**Teacher activities**	**Student's activities**	**Instructional Strategy and skills**
Step 1 Introduction	Group the students in groups. Present a chart showing the electronic configuration of nitrogen for students to observe and identify. Teacher further asks students to identify the possible oxidation number of nitrogen and discuss the occurrence of nitrogen in nature.	Listen to teacher Follow the teachers' directives	

Step 2 Laboratory preparation of nitrogen	Ask the students to explain how nitrogen can be prepared in laboratory. Show students a chart of the laboratory preparation of nitrogen from air. Ask students to identify the function of caustic soda and copper turnings respectively in the preparation of nitrogen.	Students will discuss the notes, bring out the major points and summarize for presentation.	Explanation
Step 3 Chemical method of preparing nitrogen	Teacher asks students to carry out discussion on the chemical method of preparing nitrogen. Ask students to identify two chemical method of preparing nitrogen after presenting students with chart showing the chemical methods of preparing nitrogen. Asks students to identify the various reagents involved in the process.	Students use their textbooks and research on the laboratory and industrial preparation of nitrogen. Each group present what they discovered from their groups. They now compare the teacher's notes with theirs and add points which they missed.	Explanations and use of examples
Step 4 **Evaluation/ closure**	Ask the group to present their findings to the class. Reward/praise group groups according to achievement. Teacher asks the following questions to answered by each group: 1. Describe the electronic structure of nitrogen 2. Describe the occurrence and preparation of nitrogen in the laboratory and industry 3. Describe two chemical method of	Comes out in groups to summarize points	Group presentation

	producing nitrogen		
Step 5 Summary	The teacher will ask the various groups to use different textbooks, discuss and write about the laboratory and chemical method preparation of nitrogen The teacher asks the various group to present what they discovered after which he gives them the notes below **Nature of nitrogen** Nitrogen which is in Group of the Periodic Table has five valence electrons i.e has five electrons ib the outermost shell. As a result, it achieves its stable octet structure by forming covalent bonds in its compounds. It also forms the nitride ion, N^{3-}, in combinations with the very reactive metals of Group 1 and 2. Nitrogen shows oxidation states varying from -3 to +5 in its various compounds. Nitrogen gas exists in air as a diatomic molecule with triple covalent bonds between its atoms. Nitrogen occurs chiefly as a free element in the air, making up about 78% by volume of the atmosphere. Free nitrogen in the air is important because it dilutes the oxygen to the point where combustion, respiration and oxidation of metals are reasonably slow. In the combined form, nitrogen occurs abundantly in the earth's crust as trioxonitrate(V) of sodium and calcium, as well as ammonium salt. Combined nitrogen is also found in organic matter such as proteins, urea and vitamin B compounds. **<u>Laboratory preparation of Nitrogen</u>** Since nitrogen makes up a large percentage of air, it can be obtained from air by removing the	Answer the questions	Instructional closure and questioning

other constituents. For example, carbon(IV) oxide and oxygen can be removed by passing air through caustic soda and heated copper turnings respectively. However, the nitrogen obtained this way contains about 1% by volume of rare gases as impurities, and is denser than pure nitrogen.

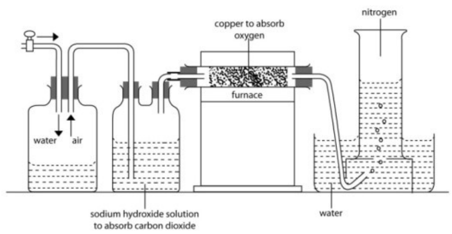


Fig. 1: Laboratory preparation of nitrogen from air

Nitrogen can also be produced by the following chemical methods:

From ammonium dioxonitrate(III): Pure nitrogen is usually obtained by thermal decomposition of ammonium dioxonitrate(III), NH_4NO_2. The dioxonitrate(III), however, is not heated directly as the reaction may get out of control and an explosion may occur. This because ammonium dioxonitrate(III) is unstable and decompose exothermically.

A mixture of sodium dioxonitrate(III) and and ammonium chloride in a ratio of 7:5 is heated to yield ammonium dioxonitrate(III), which in turn decomposes to produce nitrogen and steam. This procedure is safer than heating dioxonitrate(III) directly because ammonium dioxonitrate(III) is decoposed as fast as it is formed.

(a) $NaNO_2(aq) + NH_4CL(aq) \longrightarrow NH_4NO_2(aq) + NaCl$

(b) $NH_4NO_2(aq) \longrightarrow N_2(g) + 2H_2O(l)$

	From ammonium heptaoxodichromate(VI): When the heptapxpdichromate(VI), $(NH_4)_2Cr_2O_7$, is heated, it decomposes to yield nitrogen. $(NH_4)_2Cr_2O_7(s) \longrightarrow N_2(g) + Cr_2O_3(s) + 4H_2O(l)$ **From ammonia:** Nitrogen is liberated when ammonia is oxidized by hot copper(II) oxide. $2NH_3(g) + 3CuO(s) \longrightarrow 3Cu(s) + 3H_2O(g) + N_2(g)$ **From dinitrogen(I) oxide:** when dinitrogen(I) oxide is passed over red-hot copper, the gas is reduced to nitrogen. $N_2O(g) + Cu(s) \longrightarrow CuO(S) + N_2(g)$		

Lesson 2

Subject	: Chemistry
Week	: 6
Class	: SSII
Age	: 15+
Duration	: 45 minutes
Topic	: Nitrogen and its Compounds

Specific Objectives: By the end of the class, the students should be able to:

1. Describe in details the industrial preparation of nitrogen

Instructional materials: New school Chemistry by Osei Yaw Ababio, chart of nitrogen and its compounds, sodium dioxonitre(III), ammonium chloride, heptaoxodichromate(VI), water, litmus paper, etc.

Instructional techniques: The teacher shall employ group discussion, group presentation, group exercise in delivering the content of the topic

Entry behaviour: It is expected that students are already able to state the properties of P-block elements.

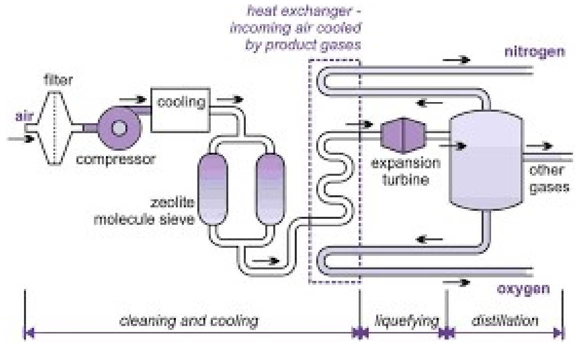
Revision of previous lesson and attendance: The teacher reviews or presents a brief summary of the last lesson and asks the students the following questions to refresh their memory:

1. Explain the electronic configuration of nitrogen
2. Describe the laboratory preparation of nitrogen

CONTENT DEVELOPMENT:

Sub topics	**Teacher activities**	**Student's activities**	**Instructional Strategy and skills**
Step 1 Introduction	Group the students in groups. Present a chart showing the industrial preparation of nitrogen.	Listen to teacher	Set induction
Step 2 **Industrial preparation of nitrogen**	Teacher set up apparatus and demonstrates the industrial preparation of nitrogen. Ask students to discuss the preparation of nitrogen in the industry. Ask students to list the reagents used and their functions.	Students will discuss the notes, bring out the major points and	Explanations and use of examples

		summarize for presentation	
Step 3 Evaluation/ closure	Ask the group to present their findings to the class. Reward/praise group groups according to achievement. Teacher asks the following questions to answered by each group: 1. Describe the industrial preparation of nitrogen 2. List two reagents and apparatus used and their functions in the laboratory preparation of nitrogen	Comes out in groups to summarize points	Group presentation
Step 4 Summary	The teacher will ask the various groups to use different textbooks, discuss and write about the industrial preparation of nitrogen. The teacher asks the various group to present what they discovered after which he gives them notes below **<u>Industrial Preparation of Nitrogen</u>** Industrially, nitrogen is prepared by the fractional distillation of liquid of liquid air. Air, from which carbon(IV) oxide has been removed, is liquefied by subjecting it to successive compression and cooling processes. Upon distillation, nitrogen gas is evolved first at -196^{o}C (at s.p.) and is separated from oxygen which boils at -183^{o}C (at s.p.). nitrogen is stored in steel cylinders and sold as liquid nitrogen or as the compressed gas.	Answers the questions	Instructional closure, questioning

	 **Fig. 2: Industrial preparation of nitrogen by fractional distillation of liquid air**		

Lesson 3

Subject : Chemistry
Week : 7
Class : SII
Age : 15+
Duration : 45 minutes
Topic : Physical, chemical properties and uses of Nitrogen

Specific Objectives : By the end of the class, the students should be able to:

1. Enumerate with equations where necessary at least two chemical and physical properties of nitrogen.
2. Highlight three uses of nitrogen

Instructional Materials: New school Chemistry by Osei Yaw Ababio, chart of nitrogen and its compounds, thermometer, magnesium, iron, calcium, gas cylinder, water, litmus paper.

Instructional techniques: The teacher shall employ group presentation.

Entry behaviour: It is expected that students are already able to describe nitrogen and its method of preparation

CONTENT DEVELOPMENT:

Sub topics	Teacher activities	Student's activities	Instructional Strategy and skills
Step 1 Revision/ Introduction	Teachers refreshes the students' memory on the previous lesson and asks the following questions 1 Describe the electronic structure of nitrogen. 2 Describe the occurrence and preparation of nitrogen in the laboratory 3 Describe two chemical method of preparing nitrogen Teacher guides students to identify the problem (physical and chemical properties of nitrogen) and write the	Listen and take down note	Revision

	topic on the board.		
Step 2 Physical and chemical properties of nitrogen	The teacher guides the students through a group presentation on the properties and uses of nitrogen Ask students to list three physical and chemical properties of nitrogen	Students discuss the physical and chemical properties of nitrogen. Listens to group discussion and ask questions.	Group presentation and discussion
Step 3 Uses of nitrogen	Teacher asks each group to write out three uses of nitrogen they can think of	Each group discuss and write out three uses of nitrogen	Group discussion, explanation.
Step 4 Evaluation/ Closure	Groups are allowed to discuss, prepare and present summaries. Teacher writes down each group strength and weaknesses in their performance. Teacher ask the following question to evaluate the students: 1. Outlist 4 physical properties of nitrogen. 2. List with equations 2 chemical properties of nitrogen. 3. Mention 3 uses of nitrogen.	Students discuss and present their findings. Answer teacher questions	Discussion, explanation,

Step 5 **Summary/ Assignment**	Teacher review the lesson and copy note for students. Teacher gives students assignment on the compounds of nitrogen to be discuss in the next class. **<u>Physical properties of Nitrogen</u>** 5. Nitrogen is a colourless, odourless and tasteless gas. 6. Pure nitrogen is slightly lighter than air 7. It is only slightly soluble in water. Two volumes of the gas dissolve 100 volumes of water at room temperature. 8. The melting point of nitrogen is -210°C and its boiling point is -196°C. These low temperatures are due to the weak van der Waals forces that exist between the nitrogen molecules in the solid and liquid states. **Chemical properties of Nitrogen** Nitrogen gas exists in air as a diatomic molecule with triple covalent bonds between its atoms. The high bond energy of the triple bond (946 $KJmol^{-1}$) makes the bond very stable and accounts for the unreactive nature of nitrogen under ordinary conditions. However, at very high temperatures and pressures, nitrogen combines directly with hydrogen, oxygen and certain metals. **With metals:** Nitrogen combines directly with very electropositive metals, e.g. magnesium, calcium, aluminium and iron, to form nitrides.	Listens and take down note.	Instructional closure.

	For example, red-hot magnesium combines directly with nitrogen to produce magnesium nitride. The nitride is readily hydrolyzed when warmed with water to give ammonia gas. **(c) $Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$** **(d) $Mg_3N_2(s) + 6H_2O(l) \xrightarrow{warm} 3Mg(OH)_2 + 2NH_3(g)$** **With non-metals:** Nitrogen combines reversibly with hydrogen to produce ammonia. It combines directly with oxygen at very high temperatures (about 2000^{o}C) or in the presence of a high voltage electric spark to form small amounts of nitrogen(II) oxide. In nature, this reaction occurs in the atmosphere when lightning flashes. **$N_2(g) + O_2(g) \longrightarrow 2NO(g)$** **Uses of Nitrogen** 4 Nitrogen is used in the industrial manufacture of ammonia, cyanide and carbamide (an important fertilizer). 5 Liquid nitrogen is used as a cooling agent. 6 Due to its inert nature, nitrogen is used; • As a carrier gas in gas chromatography; • In providing an inert atmosphere for certain industrial processes involving easily oxidizable chemicals, e.g. in making electronic components such as		

	transistors, and in the annealing of metals; As a preservative to prevent rancidity (due to the oxidation of fats) in packaged foods.		

Lesson 4

Subject	: Chemistry
Week	: 8
Class	: SS1I
Age	: 15+
Duration	: 45 minutes
Topic	: Compounds of Nitrogen

Specific Objectives: By the end of the lesson, the students should be able to:

1. Give examples of some important compounds of nitrogen
2. Describe the laboratory preparation of ammonia (NH_3)

Instructional materials: New school Chemistry by Osei Yaw Ababio, chart showing the preparation of ammonia from ammonium chloride and the Haber process, calcium hydroxide solution, water, U-tube, fractionating flask etc.

Instructional techniques: The teacher shall employ group presentations and teacher summary

Entry behaviour: It is expected that students are already able to describe the nature of nitrogen.

CONTENT DEVELOPMENT:

Sub topics	**Teacher activities**	**Student's activities**	**Instructional Strategy and skills**
Step 1 Revision of previous lesson	The teachers reviews or presents a brief summary of the last lesson and ask the students the following questions to refresh their memory: 1 Describe the occurrence and preparation of nitrogen in the laboratory and industry. 2 Outline 4 physical properties of nitrogen 3 List with equations 2 chemical properties of nitrogen 4 Mention 3 uses of Nitrogen	Answers questions	Revision of previous lesson

Step 2 Examples of compounds of nitrogen	The teacher asks students to identify the compounds of nitrogen from a chart showing various compounds of nitrogen. Ask students to identify the constituents elements present in each compound identified and calculate the oxidation number of nitrogen in each compound.	Listen to teacher, identify the compounds of nitrogen from the chart. Calculate the oxidation number of nitrogen in each compound identified.	Discussion, explanation, classification, inferring, and identification
Step 3 Nature of ammonia, laboratory preparation of ammonia	Teacher asks students to describe the nature of ammonia. Presents a video of the laboratory preparation of ammonia. Teacher asks students to discuss the laboratory preparation of ammonia.	Students discuss the nature of ammonia. Students observe critically the video showing the preparation of nitrogen. Students describe the laboratory preparation of nitrogen.	Discussion, explanation, questioning, observing, recording
Step 4 **Evaluation/ closure**	Ask groups to present their examples of compound of nitrogen to the class. Describe the nature of ammonia, laboratory preparation ammonia. Teacher ask the following questions to evaluate students: 1. Give five examples compound of nitrogen 2. How can ammonia be prepared through the Haber process	Students present their findings. Describe the nature of ammonia, laboratory prepaaration of ammonia.	Discussion, explanation
Summary/ assignment	Review the lesson and copy note for students. Give assignment for students to	Copy their notes. Take note of the	Assignment

	take home and study the industrial preparation of ammonia, the topic for next lesson discussion. **Compounds of Nitrogen** Some of the important compounds of nitrogen are ammonia and ammonium salts such as ammonium chloride (NH_4Cl), ammonium tetraoxosulphate(VI) ($(NH_4)_2SO_4$), ammonium trioxonitrate(V) (NH_4NO_3) and ammonium trioxocarbonate(IV) ($(NH_4)_2CO_3$). **Nature of ammonia** Ammonia is a hydride of nitrogen. It is a very important chemical in industry. In nature, ammonia is produced when nitrogenous matter decays in the absence of air. The decomposition may be brought about by heat or putrefying bacteria. As a result, small traces of ammonia may be present in the air. However, because of its great solubility in water, it rapidly dissolves in rain water and finds its way into the soil where it may be converted into other compounds. **Laboratory preparation of NH_3** In the laboratory, ammonia is prepared by heating any ammonium salt with no-volatile base. Usually, ammonium chloride and calcium hydroxide is chosen because it is cheap and not deliquescent like caustic alkalis. Since both the reactants are solids, they should be thoroughly ground to provide the maximum surface area for reaction.	assignment.	

	$Ca(OH)_2(s) + 2NH_4Cl(s) \rightarrow CaCl_2(s) + 2H_2O(l) + 2NH_3(g)$ The usual drying agents like conc. Tetraoxosulphate(VI) acid and fused calcium chloride are not suitable for drying ammonia because they react with the gas as follows: **$2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(s)$** **$4NH_3(g) + CaCl_2(s) \rightarrow CaCl_2.4NH_3(s)$**		

Lesson 5

Subject	: Chemistry
Week	: 9
Class	: SS1I
Age	: 15+
Duration	: 45 minutes
Topic	: Compounds of Nitrogen

Specific Objectives: By the end of the lesson, the students should be able to:

1. Describe the industrial preparation (Haber process) of ammonia
2. List two reagents and apparatus used in the Haber process and their functions

Instructional materials: New school Chemistry by Osei Yaw Ababio, chart showing the preparation of ammonia from ammonium chloride and the Haber process, calcium hydroxide solution, water, U-tube, fractionating flask etc.

Instructional techniques: The teacher shall employ group presentations and teacher summary

Entry behaviour: It is expected that students are already able to describe the nature of nitrogen.

CONTENT DEVELOPMENT:

Sub topics	**Teacher activities**	**Student's activities**	**Instructional Strategy and skills**
Step 1 Revision of previous lesson	The teachers reviews or presents a brief summary of the last lesson and ask the students the following questions to refresh their memory: 1. Describe the occurrence and preparation of nitrogen in the laboratory and industry. 2. Outline 4 physical properties of nitrogen 3. List with equations 2 chemical properties of nitrogen 4. Mention 3 uses of Nitrogen 5. Describe the laboratory preparation of ammonia	Answers questions	Revision of previous lesson

Step 2 Industrial preparation of ammonia	Teacher presents a video of the industrial preparation of ammonia. Teacher asks students to discuss the industrial preparation of ammonia.	Students observe critically the video showing the industrial preparation of nitrogen. Students describe the industrial preparation of nitrogen.	Discussion, explanation, questioning, observing, recording
Step 4 Evaluation/ closure	Ask groups to the industrial preparation ammonia. Teacher ask the following questions to evaluate students: 1. How can ammonia be prepared through the Haber process 2. Enumerates two apparatus and reagents used in the Haber process of preparing ammonia	Students present their findings. Describe the industrial (Haber process) preparation of ammonia	Discussion, explanation
Summary/ assignment	Review the lesson and copy note for students. Give assignment for students to take home and study the physical and chemical properties of ammonia, uses of ammonia, the topic for next lesson discussion. **Industrial preparation NH_3 (Haber process)** Ammonia is manufactured from nitrogen and hydrogen by the Haber process. Since the direct combination between nitrogen and hydrogen is reversible, special conditions of reaction are necessary for the optimum yield of	Copy their notes. Take note of the assignment.	Assignment

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ammonia. Basically, the process involves mixing nitrogen and hydrogen in the volume ratio of 1:3 and passing the mixture;

• Over finely divided iron (catalyst),
• At a temperature of about 450^{o}C, and
• A pressure of about 200 atmospheres.

The yield of ammonia is about 15% under these conditions. The ammonia is then liquefied by cooling, and the unused gases are re-circulated over the catalyst for further production of ammonia.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ + heat

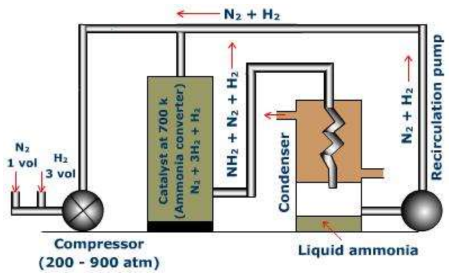

Fig. 3: Preparation of Ammonia by the Haber Process
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Lesson 6

Subject : Chemistry

Week : 10

Class : SII

Age : 15+

Duration : 45 minutes

Topic : Physical, chemical properties and uses of HN_3

Specific Objectives: By the end of the class, the students should be able to:

3. States any 5 physical and chemical properties of NH_3
4. Give the uses of NH_3

Instructional Materials: New school Chemistry by Osei Yaw Ababio, chart of sulphur and its compounds, sulphuric acid, water, litmus paper.

Instructional techniques: The teacher shall employ group presentation

Entry behaviour: it is expected that students are already able to describe sulphure and its allotropes.

CONTENT DEVELOPMENT:

Sub topics	Teacher activities	Student's activities	Instructional Strategy and skills
Step 1 Revision	Teachers refreshes the students' memory on the previous lesson and asks the following questions: 1 Give examples of some important compounds of nitrogen 2 Describe the haber process of the preparation of NH_3	Answers question	Revision
Step 2 Introduction	The teacher presents a sample of ammonia for the students to observe and write down their observation.	Students observe ammonia and write down their observation.	Giving instruction, observation

Step 3 **Physical and chemical properties of ammonia**	Teacher asks students to write out their observation about ammonia. Teacher guide students to discuss the physical and chemical properties of ammonia.	Students observe a sample of ammonia. Discuss the physical and chemical properties of ammonia.	Observation, questioning, discussion
Step 4 **Uses of ammonia**	Teacher asks students to explain the uses of ammonia in laundry. List five uses of ammonia	Discuss the uses of ammonia in the laundry. List the uses of ammonia.	Discussion, explanation
Step 5 **Evaluation/closure**	Ask group to present their conclusion to the class. Describe the physical and chemical properties of ammonia. Highlight the uses of ammonia with emphasis on its laundry uses.	Presents their findings to whole class. Groups receive reward.	Presentation and demonstration of knowledge of the topic.
Step 6 **Summary/assignment**	Review the lesson and copy note for students. Give assignment for students to go home and study the oxides of nitrogen, the topic for next lesson's discussion. **Physical Properties of NH_3** 7. Ammonia is a colourless gas with a characteristic choking smell 8. In large quantities, ammonia is poisonous because of its effect on the respiratory muscles. 9. It is an alkaline gas, changing moist red litmus paper blue. 10. It is about 1.7 times less dense than air. 11. Ammonia changes into liquid at -	Copy their notes. Take note of the assignment.	Assignment

	34.4°C. It is easily liquefied into a colourless liquid at ordinary temperatures by compression, and is transported in this form. 12. Ammonia has a boiling point of -77.7°C which is relatively high when compared with other similar compounds because of the presence of hydrogen bonding between its molecules. **Chemical properties of NH_3** **Reaction with Oxygen:** Ammonia does not burn in air, but it burns readily in oxygen with a greenish-yellow flame to form water vapour and nitrogen. $4NH_3(g) + 3O_2(g) \rightarrow 6H_2O(g) + 2N_2(g)$ **Ammonia as a reducing agent** **With copper(II) oxide:** Ammonia is not a strong reducing agent. However, it reduces heated copper(II) oxide to copper while it is itself oxidized to water and nitrogen. $3CuO(s) + 2NH_3(g) \rightarrow 4Cu(s) + 3H_2O(l) + N_2(g)$ **With chlorine:** In excess, ammonia first reduces chlorine to produce hydrogen chloride and nitrogen. Then the hydrogen chloride reacts with the excess ammonia to produce white fumes of ammonium chloride. (c) $2NH_3(g) + Cl_2(g) \rightarrow 6HCl(g) + N_2(g)$ (d) $6NH_3(g) + 6HCl(g) \rightarrow 6NH_4Cl(s)$ **Reaction with Carbon(IV) oxide:** Ammonia reacts with carbon(IV) oxide at		

	150°C and a high pressure of 150atm to produce urea, an important organic compound. **$2NH_3(g) + CO_2(g) \longrightarrow (NH_2)_2CO(s) + H_2O(l)$** **Thermal decomposition:** Ammonia is decomposed at temperatures above 500°C or prolonged sparking to yield nitrogen and hydrogen. **As a base:** Ammonia is a weak base because it can accept protons to form ammonium ions. It reacts with acids to form ammonium salts. **$NH_3(g) + H^+(aq) \rightleftharpoons NH_4^+(aq)$** **$2NH_3(g) + H_2SO_4(aq) \longrightarrow (NH_4)_2SO_4(s)$** **Uses of HN_3** 6. Aqueous ammonia is used in softening temporarily hard water. 7. Aqueous ammonia is also used in laundries as a solvent for removing grease and oil stains. 8. Liquid ammonia is used as a refrigerant, although it is now being replaced by less toxic and unreactive fluorocarbons. 9. Ammonia is used in the manufacture of trioxonitrate(V) acid and sodium trioxocarbonate(IV) by the Solvay process. The most important use of ammonia is in the manufacture of nitrogenous fertilizers like ammonium tetraoxosulphate(VI), ammonium trioxonitrate(V), carbamide, and ammonium tetraoxosulphate(V).		

APPENDIX C

LESSON PLAN FOR LECTURE METHOD

Lesson 1

Subject : Chemistry
Week : 5
Class : SSII
Age : 15+
Duration : 45 minutes
Topic : Nitrogen and its Compounds

Specific Objectives: By the end of the class, the students should be able to:

1. Describe the electronic structure and occurrence of Nitrogen
2. Describe the laboratory and chemical method preparation of nitrogen

Instructional materials: New school Chemistry by Osei Yaw Ababio, chart of nitrogen and its compounds, sodium dioxonitre(III), ammonium chloride, heptaoxodichromate(VI), water, litmus paper, etc.

Entry behaviour: It is expected that students are already able to state the properties of P-block elements.

Revision of previous lesson and attendance: The teacher reviews or presents a brief summary of the last lesson and asks the students the following questions to refresh their memory:

1. Give 2 uses of any oxide of sulphur
2. Give any 4 uses of tetraoxosulphate (VI) acid

CONTENT DEVELOPMENT:

Sub topics	**Teacher activities**	**Student's activities**	**Instructional Strategy and skills**
Step 1 Introduction	Teacher introduces the topic and writes nitrogen on the chalk board	Listen to teacher	
Step 2 Nitrogen	Teacher explains that Nitrogen which is in Group of the Periodic Table has five valence electrons i.e has five electrons ib the	Listen and take down points	Explanation

	outermost shell. As a result, it achieves its stable octet structure by forming covalent bonds in its compounds. It also forms the nitride ion, N^{3-}, in combinations with the very reactive metals of Group 1 and 2. Nitrogen shows oxidation states varying from -3 to +5 in its various compounds. Nitrogen gas exists in air as a diatomic molecule with triple covalent bonds between its atoms. Nitrogen occurs chiefly as a free element in the air, making up about 78% by volume of the atmosphere. Free nitrogen in the air is important because it dilutes the oxygen to the point where combustion, respiration and oxidation of metals are reasonably slow. In the combined form, nitrogen occurs abundantly in the earth's crust as trioxonitrate(V) of sodium and calcium, as well as ammonium salt. Combined nitrogen is also found in organic matter such as proteins, urea and vitamin B compounds.		
Step 3 Laboratory preparation of nitrogen	**<u>Laboratory preparation of Nitrogen</u>** Since nitrogen makes up a large percentage of air, it can be obtained from air by removing the other constituents. For example, carbon(IV) oxide and oxygen can be removed by passing air through caustic soda and heated copper turnings respectively. However, the nitrogen obtained this way contains about 1% by volume of rare gases as impurities, and is denser than	Listen and take down points Ask questions	Explanations and use of examples

pure nitrogen.

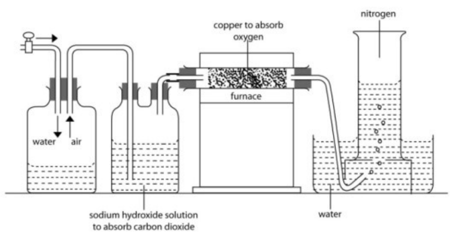


Fig. 1: Laboratory preparation of nitrogen from air

Nitrogen can also be produced by the following chemical methods:

From ammonium dioxonitrate(III): Pure nitrogen is usually obtained by thermal decomposition of ammonium dioxonitrate(III), NH_4NO_2. The dioxonitrate(III), however, is not heated directly as the reaction may get out of control and an explosion may occur. This because ammonium dioxonitrate(III) is unstable and decompose exothermically.

A mixture of sodium dioxonitrate(III) and and ammonium chloride in a ratio of 7:5 is heated to yield ammonium dioxonitrate(III), which in turn decomposes to produce nitrogen and steam. This procedure is safer than heating dioxonitrate(III) directly because ammonium dioxonitrate(III) is decoposed as fast as it is formed.

(a) $NaNO_2(aq) + NH_4CL(aq) \longrightarrow NH_4NO_2(aq) + NaCl$

(b) $NH_4NO_2(aq) \longrightarrow N_2(g) + 2H_2O(l)$

From ammonium

	heptaoxodichromate(VI): When the heptapxpdichromate(VI), $(NH_4)_2Cr_2O_7$, is heated, it decomposes to yield nitrogen. $(NH_4)_2Cr_2O_7(s) \longrightarrow N_2(g) + Cr_2O_3(s) + 4H_2O(l)$ **From ammonia:** Nitrogen is liberated when ammonia is oxidized by hot copper(II) oxide. $2NH_3(g) + 3CuO(s) \longrightarrow 3Cu(s) + 3H_2O(g) + N_2(g)$ **From dinitrogen(I) oxide:** when dinitrogen(I) oxide is passed over red-hot copper, the gas is reduced to nitrogen. $N_2O(g) + Cu(s) \longrightarrow CuO(S) + N_2(g)$		
Step 4 Summary	Teacher summarizes the important points of the lesson	Listen to the teachers and ask questions	Instructional closure
Step 5 Evaluation	Teacher asks the following questions: 1 Describe the electronic structure of nitrogen 2 Describe the occurrence and preparation of nitrogen in the laboratory 3 Describe two chemical method of producing nitrogen	Answers the questions	Questioning

Lesson 2

Subject : Chemistry
Week : 6
Class : SSII
Age : 15+
Duration : 45 minutes
Topic : Industrial preparation of nitrogen

Specific Objectives: By the end of the class, the students should be able to:

3. Describe the electronic structure and occurrence of Nitrogen
4. Describe the laboratory and chemical method preparation of nitrogen

Instructional materials: New school Chemistry by Osei Yaw Ababio, chart of nitrogen and its compounds, sodium dioxonitre(III), ammonium chloride, heptaoxodichromate(VI), water, litmus paper, etc.

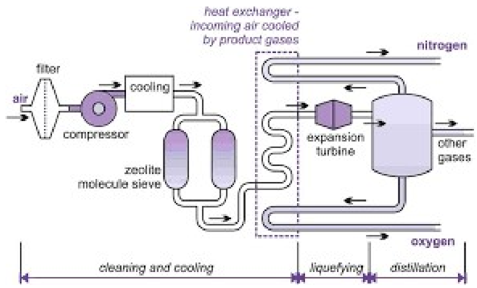
Entry behaviour: It is expected that students are already able to state the properties of P-block elements.

Revision of previous lesson and attendance: The teacher reviews or presents a brief summary of the last lesson and asks the students the following questions to refresh their memory:

1. Draw the electronic configuration of nitrogen
2. Describe the laboratory preparation of nitrogen

CONTENT DEVELOPMENT:

Sub topics	Teacher activities	Student's activities	Instructional Strategy and skills
Step 1 Introduction	Teacher introduces the topic and writes industrial preparation of nitrogen on the chalk board	Listen to teacher	
Step 2 Industrial preparation of Nitrogen	Teacher explains that Industrially, nitrogen is prepared by the fractional distillation of liquid of liquid air. Air, from which carbon(IV) oxide has been removed, is liquefied by subjecting it to successive compression	Listen and take down points	Explanation

	and cooling processes. Upon distillation, nitrogen gas is evolved first at -196^oC (at s.p.) and is separated from oxygen which boils at -183^oC (at s.p.). nitrogen is stored in steel cylinders and sold as liquid nitrogen or as the compressed gas.  **Fig. 2: Industrial preparation of nitrogen by fractional distillation of liquid air**		
Step 5 **Summary**	Teacher summarizes the important points of the lesson	Listen to the teachers and ask questions	Instructional closure
Step 6 Evaluation	Teacher asks the following questions: 1. Describe the industrial preparation of nitrogen 2. List two apparatus used in the in the industry to prepare nitrogen	Answers the questions	Questioning

Lesson 3

Subject : Chemistry

Week : 7

Class : SII

Age : 15+

Duration : 45 minutes

Topic : Physical, chemical properties and uses of Nitrogen

Specific Objectives : By the end of the class, the students should be able to:

4. Enumerate with equations where necessary at least two chemical and physical properties of nitrogen.
5. Highlight three uses of nitrogen

Instructional Materials: New school Chemistry by Osei Yaw Ababio, chart of nitrogen and its compounds, thermometer, magnesium, iron, calcium, gas cylinder, water, litmus paper.

Instructional techniques: The teacher shall employ group presentation.

Entry behaviour: It is expected that students are already able to describe nitrogen and its method of preparation

CONTENT DEVELOPMENT:

Sub topics	**Teacher activities**	**Student's activities**	**Instructional Strategy and skills**
Step 1 Revision/ Introduction	Teachers refreshes the students' memory on the previous lesson and asks the following questions 1 Describe the electronic structure of nitrogen. 2 Describe the occurrence and preparation of nitrogen in the laboratory 3 Describe two chemical method of preparing nitrogen Teacher introduces the lesson and write the topic physical and chemical properties of nitrogen on the board.	Answers question	Revision

Step 2 Physical and chemical properties of nitrogen	**<u>Physical properties of Nitrogen</u>** 9. Nitrogen is a colourless, odourless and tasteless gas. 10. Pure nitrogen is slightly lighter than air 11. It is only slightly soluble in water. Two volumes of the gas dissolve 100 volumes of water at room temperature. 12. The melting point of nitrogen is -210°C and its boiling point is -196°C. These low temperatures are due to the weak van der Waals forces that exist between the nitrogen molecules in the solid and liquid states. **Chemical properties of Nitrogen** Nitrogen gas exists in air as a diatomic molecule with triple covalent bonds between its atoms. The high bond energy of the triple bond (946 $KJmol^{-1}$) makes the bond very stable and accounts for the unreactive nature of nitrogen under ordinary conditions. However, at very high temperatures and pressures, nitrogen combines directly with hydrogen, oxygen and certain metals. **With metals:** Nitrogen combines directly with very electropositive metals, e.g. magnesium, calcium, aluminium and iron, to form nitrides. For example, red-hot magnesium combines directly with nitrogen to produce magnesium nitride. The nitride is readily hydrolyzed when warmed with water to give ammonia gas. **(e)** $Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$ **(f)** $Mg_3N_2(s) + 6H_2O(l) \xrightarrow{warm} 3Mg(OH)_2 + 2NH_3(g)$	Take down notes as they listen to the teacher	Explanations and stimulus variations

	With non-metals: Nitrogen combines reversibly with hydrogen to produce ammonia. It combines directly with oxygen at very high temperatures (about 2000°C) or in the presence of a high voltage electric spark to form small amounts of nitrogen(II) oxide. In nature, this reaction occurs in the atmosphere when lightning flashes. $N_2(g) + O_2(g) \longrightarrow 2NO(g)$		
Step 3 Uses of nitrogen	**Uses of Nitrogen** 4. Nitrogen is used in the industrial manufacture of ammonia, cyanide and carbamide (an important fertilizer). 5. Liquid nitrogen is used as a cooling agent. 6. Due to its inert nature, nitrogen is used; • As a carrier gas in gas chromatography; • In providing an inert atmosphere for certain industrial processes involving easily oxidizable chemicals, e.g. in making electronic components such as transistors, and in the annealing of metals; As a preservative to prevent rancidity (due to the oxidation of fats) in packaged foods.	Listen ask questions	Explanations, use of example and stimulus variation
Step 4 Summary	The teacher summarizes the main points of the lesson	Listen to the teachers and ask questions	Instructional closure
Step 5 Evaluation	1 Outlist 4 physical properties of nitrogen. 2 List with equations 2 chemical	Answers the questions	questioning

	properties of nitrogen. 3 Mention 3 uses of nitrogen. Teacher ask students to read on the physical and chemical properties ammonia.		

Lesson 4

Subject	: Chemistry
Week	: 8
Class	: SS1I
Age	: 15+
Duration	: 45 minutes
Topic	: Compounds of Nitrogen

Specific Objectives: By the end of the lesson, the students should be able to:

1. Give examples of some important componds of nitrogen
2. Describe the laboratory preparation of ammonia (NH_3)

Instructional materials: New school Chemistry by Osei Yaw Ababio, chart showing the preparation of ammonia from from ammonium chloride and the Haber process, calcium hydroxide solution, water, U-tube, fractionating flask etc.

Entry behaviour: It is expected that students are already able to describe nitrogen.

CONTENT DEVELOPMENT:

Sub topics	**Teacher activities**	**Student's activities**	**Instructional Strategy and skills**
Step 1 Revision of previous lesson/ Introduction	The teachers reviews or presents a brief summary of the last lesson and ask the students the following questions to refresh their memory: 1. Describe the occurrence and preparation of nitrogen 2. Outlist 5 physical properties of nitrogen 3. List with equations 3 chemical properties of nitrogen 4. Mention 3 uses of nitrogen 5. Explain the laboratory and industrial preparation of nitrogen Teacher introduces the lesson by writing compound of nitrogen on the board. **Compounds of Nitrogen** Some of the important compounds of	Answers questions Take down notes Students attempt to answer the question	Revision of previous lesson Set induction explanations

	nitrogen are ammonia and ammonium salts such as ammonium chloride (NH_4Cl), ammonium tetraoxosulphate(VI) ($(NH_4)_2SO_4$), ammonium trioxonitrate(V) (NH_4NO_3) and ammonium trioxocarbonate(IV) ($(NH_4)_2CO_3$).		
Step 2 **Ammonia**	Teacher explains Ammonia is a hydride of nitrogen. It is a very important chemical in industry. In nature, ammonia is produced when nitrogenous matter decays in the absence of air. The decomposition may be brought about by heat or putrefying bacteria. As a result, small traces of ammonia may be present in the air. However, because of its great solubility in water, it rapidly dissolves in rain water and finds its way into the soil where it may be converted into other compounds. **Laboratory preparation of NH_3** In the laboratory, ammonia is prepared by heating any ammonium salt with no-volatile base. Usually, ammonium chloride and calcium hydroxide is chosen because it is cheap and not deliquescent like caustic alkalis. Since both the reactants are solids, they should be thoroughly ground to provide the maximum surface area for reaction. **$Ca(OH)_2(s) + 2NH_4Cl\ (s) \rightarrow CaCl_2(s) + 2H_2O(l) + 2NH_3(g)$** The usual drying agents like conc. Tetraoxosulphate(VI) acid and fused calcium chloride are not suitable for	Take down notes And listen to the teacher	Use of explanation

	drying ammonia because they react with the gas as follows: **$2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(s)$** **$4NH_3(g) + CaCl_2(s) \rightarrow CaCl_2.4NH_3(s)$**		
Step 3 Summary	Summarizes the main points of the lesson	Listen to the teachers and ask questions	Instructional closure
Step 4 Evaluation	Teacher asks the following questions: 1 Give examples of some important compounds of nitrogen 2 Describe the laboratory preparation of NH_3 **Assignment:** teacher ask students to read on compound of nitrogen	Answers the questions	questioning

Lesson 5

Subject	: Chemistry
Week	: 9
Class	: SS1I
Age	: 15+
Duration	: 45 minutes
Topic	: Industrial preparation of ammonia

Specific Objectives: By the end of the lesson, the students should be able to:

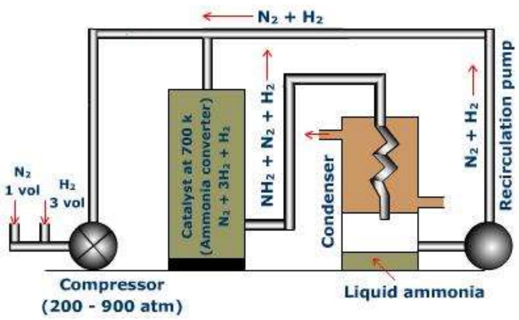
1. Describe the industrial preparation of ammonia.
2. State two reagents and their functions used in the preparation of ammonia in the industry

Instructional materials: New school Chemistry by Osei Yaw Ababio, chart showing the preparation of ammonia from from ammonium chloride and the Haber process, calcium hydroxide solution, water, U-tube, fractionating flask etc.

Entry behaviour: It is expected that students are already able to describe the laboratory preparation of nitrogen.

CONTENT DEVELOPMENT:

Sub topics	Teacher activities	Student's activities	Instructional Strategy and skills
Step 1 Revision of previous lesson/ Introduction	The teachers reviews or presents a brief summary of the last lesson and ask the students the following questions to refresh their memory: 1. Describe the laboratory preparation of ammonia 2. Outlist 5 compounds of nitrogen Teacher introduces the lesson by writing industrial preparation of ammonia on the board.	Answers questions Students attempt to answer the question	Revision of previous lesson Set induction
Step 2 Industrial preparation of ammonia	Teacher explains **Industrial preparation NH_3 (Haber process)**	Take down notes	Use of explanation

	Ammonia is manufactured from nitrogen and hydrogen by the Haber process. Since the direct combination between nitrogen and hydrogen is reversible, special conditions of reaction are necessary for the optimum yield of ammonia. Basically, the process involves mixing nitrogen and hydrogen in the volume ratio of 1:3 and passing the mixture; • Over finely divided iron (catalyst), • At a temperature of about 450^{o}C, and • A pressure of about 200 atmospheres. The yield of ammonia is about 15% under these conditions. The ammonia is then liquefied by cooling, and the unused gases are re-circulated over the catalyst for further production of ammonia. **$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ + heat**  **Fig. 3: Preparation of Ammonia by the Haber Process**	And listen to the teacher	
Step 3 Summary	Summarizes the main points of the lesson	Listen to the teachers and ask questions	Instructional closure

Step 4 Evaluation	Teacher asks the following questions: 1. Explain the industrial preparation of ammonia 2. List two reagents used in the above process **Assignment:** teacher ask students to read on physical and chemical properties of ammonia; and uses of ammonia	Answers the questions	questioning

Lesson 6

Subject : Chemistry

Week : 10

Class : SII

Age : 15+

Duration : 45 minutes

Topic : Physical properties and uses of HN_3

Specific Objectives: By the end of the class, the students should be able to:

1. States any 5 physical and chemical properties of NH_3
2. Give the uses of NH_3

Instructional Materials: New school Chemistry by Osei Yaw Ababio, chart of nitrogen and its compounds, ammonia, water, litmus paper.

Entry behaviour: it is expected that students are already able to describe sulphure and its allotropes.

CONTENT DEVELOPMENT:

Sub topics	**Teacher activities**	**Student's activities**	**Instructional Strategy and skills**
Step 1 Revision/ Introduction	Teachers refreshes the students' memory on the previous lesson and asks the following questions: 1 Give examples of some important compounds of nitrogen 2 Describe the haber process of the preparation of NH_3 Teacher writes on the board the topic of the day "physical and chemical properties of ammonia"	Answers question	Revision
Step 2 Physical and chemical properties of NH_3	**Physical Properties of NH_3** 13. Ammonia is a colourless gas with a characteristic choking smell 14. In large quantities, ammonia is poisonous because of its effect on the respiratory muscles.	Take down notes as they listen to the teacher	Explanations and stimulus variations

15. It is an alkaline gas, changing moist red litmus paper blue.
16. It is about 1.7 times less dense than air.
17. Ammonia changes into liquid at -34.4^{o}C. It is easily liquefied into a colourless liquid at ordinary temperatures by compression, and is transported in this form.
18. Ammonia has a boiling point of -77.7^{o}C which is relatively high when compared with other similar compounds because of the presence of hydrogen bonding between its molecules.

Chemical properties of NH_3

Reaction with Oxygen: Ammonia does not burn in air, but it burns readily in oxygen with a greenish-yellow flame to form water vapour and nitrogen.

$$4NH_3(g) + 3O_2(g) \rightarrow 6H_2O(g) + 2N_2(g)$$

Ammonia as a reducing agent

With copper(II) oxide: Ammonia is not a strong reducing agent. However, it reduces heated copper(II) oxide to copper while it is itself oxidized to water and nitrogen.

$$3CuO(s) + 2NH_3(g) \rightarrow 4Cu(s) + 3H_2O(l) + N_2(g)$$

With chlorine: In excess, ammonia first reduces chlorine to produce hydrogen chloride and nitrogen. Then the hydrogen chloride reacts with the excess ammonia to produce white fumes of ammonium chloride.

(e) $2NH_3(g) + Cl_2(g) \rightarrow 6HCl(g) +$

	$N_2(g)$ (f) $6NH_3(g) + 6HCl(g) \rightarrow 6NH_4Cl(s)$ **Reaction with Carbon(IV) oxide:** Ammonia reacts with carbon(IV) oxide at 150°C and a high pressure of 150atm to produce urea, an important organic compound. $2NH_3(g) + CO_2(g) \rightarrow (NH_2)_2CO(s) + H_2O(l)$ **Thermal decomposition:** Ammonia is decomposed at temperatures above 500°C or prolonged sparking to yield nitrogen and hydrogen. **As a base:** Ammonia is a weak base because it can accept protons to form ammonium ions. It reacts with acids to form ammonium salts. $NH_3(g) + H^+(aq) \rightleftharpoons NH_4^+(aq)$ $2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(s)$		
Step 3 Uses of NH_3	**Uses of HN_3** 1 Aqueous ammonia is used in softening temporarily hard water. 2 Aqueous ammonia is also used in laundries as a solvent for removing grease and oil stains. 3 Liquid ammonia is used as a refrigerant, although it is now being replaced by less toxic and unreactive fluorocarbons. 4 Ammonia is used in the manufacture of trioxonitrate(V) acid and sodium trioxocarbonate(IV) by the Solvay process.	Listen ask questions	Explanations, use of example and stimulus variation

	1. The most important use of ammonia is in the manufacture of nitrogenous fertilizers like ammonium tetraoxosulphate(VI), ammonium trioxonitrate(V), carbamide, and ammonium tetraoxosulphate(V).		
Step 4 Summary	The teacher summarizes the main points of the lesson	Listen to the teachers and ask questions	Instructional closure
Step 5 Evaluation	1 Outlist any 5 physical and chemical properties of NH_3 2 Mention any 8 uses of NH_3	Answers the questions	questioning

APPENDIX D

CHEMISTRY ACHIEVMENT TEST (CAT)

NAME OF STUDENT: DATE:

GENDER: Male ( ) Female ( ) TIME: 50 MINUTES

Instruction: Circle the correct answer from the options provided

1. Nitrogen belongs to group _ of the periodic table A. 6 B. 2 C. 4 D. 5
2. Nitrogen forms the nitride ion, N^{3-} in combinations with the very reactive metals of Groups A. 1 & 2 B. 2 & 3 C. 3 & 4 D. 4 & 5
3. The oxidation state of nitrogen can range from A +3 to -5 B +5 to -3 C -5 to +3 D -3 to +5
4. In the combined form, nitrogen occurs abundantly in the earth's crust as trioxonitrates(V) of – and ---- A. Calcium and Magnessium B. Sodium and Calcium C. Sodium and Chlorine D. Potassium and Calcium
5. The process for the extraction of Nitrogen is called ____ A. Fractional distillation of liquid air B. Fractional distillation of moist air C. Fractional distillation of dry air D. Fractional distillation of rotten air
6. Nitrogen occurs chiefly as a free element in the air, making up about – by volume of the atmosphere A. 87% B. 8.7% C. 78% D. 77%
7. Carbon(IV) oxide and oxygen can be removed by passing air through – and – respectively in the laboratory preparation of nitrogen. A. Caustic soda and heated copper turnings B. Soda lime and heated sodium crystals C. Lime water and ethanol D. None of the above
8. Ammonium dioxonitrate(III) is not heated directly in the preparation of pure nitrogen because---------- A. its unstable and decomposes exothermically B. its unstable and decomposes endothermically C. its stable and doesn't decompose on heating D. none of the above.
9. Nitrogen combines with metals to form ---- A. Nitrates B. Nitric acid C. Nitrides D. Nitrites
10. Nitrogen can be produced by the following chemical methods except A. From ammonium dioxonitrate(III) B. From ammonium tetrachloride C. From ammonia D. From ammonia
11. Nitrogen combines directly with red-hot magnesium to produce magnesium nitride which is readily -------- when warmed with water to give ammonia. A. vapourized B. hydrolyzed C. sublimate D. hypnothize.
12. Nitrogen is used in one of the following A. fireworks B. matches C. gunpowder D. Laundries
13. Ammonia is manufactured by __ process A. Haber B. Frasch C. Contact D. Marsh

14. Nitrogen combines directly with oxygen at very high temperature to produce small amounts of— A. Nitrogen(I) oxide B. Nitrogen(III) oxide C. Nitrogen(II) oxide D. Nitrogen(IV) oxide
15. A concentrated solution of ammonia known as 880 ammonia has a density of -- A 0.88 g cm^{-3} B 1.84 g cm^{-3} C 8.14 g cm^{-3} D 1.48 g cm^{-3}
16. Which of the following is used in softening temporarily hard water A. Aqueous ammonium B. Aqueous ammonia C. Aqueous ammonium chloride D. Ammonia
17. One very important and worldwide use of nitrogen is in the making of ___A. Film straps B. Fertilizer C. Chemicals D. Dehydrating agents
18. The type of bond in N-H is A. ionic bond B. Dative bond C. Covalent bond D. Hydrogen bond
19. In the presence of ---- catatlyst, ammonia reacts with excess air to produce Nitrogen(II) oxide and water A. lead B. Nickel C. Palladium D. Platinum
20. Which of the following is not an ammonium salt A. Ammonium chloride B. Ammonium sulphate C. Ammonium carbonate D. Ammonium phosphate
21. ----- reacts with carbon(IV) oxide at 150^0C and a high pressure of 150atm to produce urea A. Nitrogen B. Ammonia C. Nitrous oxide D. None of the above
22. The melting point of Nitrogen is A. -210 ^{o}C B. -196^{o}C C. 191^{o}C D. 119^{o}C
23. Nitrogen is used as a carrier gas in gas chromatography due to ----- A. electronegativity B. high electron affinity C. inert nature D. all of the above.
24. Which of these is a hydride of nitrogen---- A. carbon(IV) oxide B. Hydrogen Chloride C. ammonia D hydrogen sulphide.
25. What is the molecular formula of slaked lime ------- A. $Ca(OH)_2$ B. CaO C. NaOH D. KOH
26. The mixing of nitrogen and hydrogen in the Haber process is in the ratio of --- to --- A. 3:1 B. 1:3 C. 1:2 D. 2:1.
27. In the ammonia molecule there are ----- A. three single covalent bonds and a pair of lone electrons B. three single covalent bonds two pair of lone electrons C. two covalent and one electrovalent bond D none of the above.
28. Ammonia is not a strong reducing agent. However, it reduces heated copper(II) oxide to copper while it is itself oxidized to ----- and ------ A. acid and base B. water and nitrogen C. acid and water D. nitrogen and base.
29. ----- mole of ammonia reacted with one mole of carbon(IV) oxide to produce one mole of urea and water respectively in the equation below; $2NH_3(g) + CO_2(g) \rightarrow (NH_2)_2CO(s) + H_2O(l)$. A. 1 B. 2 C. 3 D. 4
30. Which of these is a chemical property of ammonia A. combustion B. thermal decomposition C. ammonia as a reducing agent D. all of the above.

31. The turning of damp red litmus paper to blue is a test for ----- A. nitrogen B. ammonia C. ammonium chloride D. nitride
32. What is the oxidation number of nitrogen in hydroxylamine A. +1 B. -1 C. +2 D. -2
33. Nitrogen gas exists in air as a diatomic molecule with triple covalent bonds which are made up of --- A. one sigma and two pi-bond B. two sigma and one pi-bond C. three pi-bond D. three sigma bond.
34. ------- is a colourless, odourless and tasteless gas A. oxygen B. sulphur C. nitrogen D. calcium.
35. Ammonia does not burn in air, but it burns readily in oxygen with a -------- to form water vapour and nitrogen A. Dark-blue flame B. greenish-yellow flame C. yellow flame D. greenish-brown.
36. Ammonia is about ------ times less dense than air… A. 2 B. 1.7 C. 2.1 D. 3.2.
37. ------- is the first oxide of nitrogen identified A. N_2O B. NO_2 C. NO D. NO_3
38. Dinitrogen(I) oxide was discovered by ----- A. Priestley B. Cavandish C. Aristotle D. Dalton
39. Which of these is not a property of N_2O ----- A. it is a colourless, poisonous gas B. it is almost insoluble in water C. it is slightly denser than air D. it turns blue litmus red.
40. -------- is the reddish-brown gas given off when the trioxonitrates(V) of heavy metals are heated. A. N_2O B. NO_2 C. NO D. NO_3.
41. Nitrogen(II) oxide was discovered by Cavendish in what year---- A. 1919 B. 1980 C. 1977 D. 1978.
42. Why is calcium hydroxide used in the laboratory preparation of ammonia …. A. it is cheap and not deliquescent B. it is cheap and deliquescent C. it is cheap and hygroscopic D. none of the above.
43. Tetraoxosulphate(VI) acid and fused calcium chloride are not suitable for drying ammonia because—A. they react with ammonia gas B. they do not react with ammonia gas C. they are inert D. all of the above.
44. ------ discolourises acidified potassium tetraoxomanganate(VII) very slowly… A. N_2O B. NO_2 C. NO D. NO_3.
45. Nitrogen(IV) oxide dissolves in water to form a mixture of ------- and --------- A. dioxonitrate(III) and trioxonitrate(V) acids B. trioxonitrate (V) and tetraoxonitrate(VI) acids C. trioxonitrate(V) and trioxonitrtae(V) D. none of the above.
46. HNO_3 was first prepared by ------- in 1658 A. Charles B. Boyle C. Glauber D. Bohr.
47. Which of these is not a physical property of nitrogen(IV) oxide A. it is a reddish-brown gas B. it has an irritating smell C. it is poisonous D. it is lesser than air
48. ----- are electrovalent compounds which contain the ammonium ion, NH_4^+, as cation A. ammonium salt B. ammonium acid C. ammonium base D. ammonium water.

49. When dinitrogen(I) oxide is passed over red-hot copper, the gas is reduced to ---- A. nitrogen B. oxygen C. hydrogen D. all of the above.
50. The bond energy of the triple bond in nitrogen is ---- A. $669kJmol^{-1}$ B. $946kJmol^{-1}$ C. $472kJmol^{-1}$ D. $511kJmol^{-1}$

APPENDIX E

Table of specification on Chemistry Achievement Test (CAT) Blue Print

Content Area	Sub units	Mental Skills						
		Lower Order		Higher Order				
		Knowledge (30%)	Comprehension (22%)	Application (14%)	Analysis (14%)	Synthesis (10%)	Evaluation (10%)	Total (100%)
Nitrogen	Nitrogen (N)	2	1	1				4
	Laboratory/industrial preparation of nitrogen	3	1	2	2	2		10
	Uses, physical/chemical properties of N	3	2	1	1		3	10
Compounds of Nitrogen	Ammonia	3	3	1		1		8
	Industrial preparation	2	2	1	3	1	1	10
	Uses	2	2	1	1	1	1	8
Total		15	11	7	7	5	5	50

Appendix F

Marking Scheme for CAT

1	D	11	A	21	B	31	B	41	C
2	A	12	D	22	A	32	B	42	A
3	D	13	A	23	C	33	A	43	A
4	B	14	C	24	C	34	C	44	C
5	A	15	A	25	A	35	B	45	A
6	C	16	B	26	B	36	B	46	C
7	A	17	B	27	A	37	A	47	D
8	A	18	C	28	B	38	A	48	A
9	C	19	D	29	B	39	D	49	A
10	B	20	D	30	D	40	B	50	B

Appendix G

Calculations for reliability coefficient (r) on achievement test for 30 students

Scores of the students on total test obtained from testing are shown below

37	17	31	10	30	25
20	27	12	26	25	19
22	23	41	19	21	25
28	39	40	17	16	19
24	23	21	38	25	32

$$r = \frac{Kd^2 - \overline{X}(K - \overline{X})}{d^2(K-1)}$$

Where,

K = number of items = 50

$\overline{X}$= mean score = 25.07

d = standard deviation = 8.09

$$\boldsymbol{r} = \frac{50(8.09)^2 - 25.07\,(50 - 25.07)}{8.09^2(50-1)}$$

$$r = \frac{2647.4099}{3206.9569} = 0.83$$

Appendix H

Population of SSII chemistry students in Delta Central Senatorial District of Delta State

S/No	Name of School	Town	LGA	Number of chemistry students	
				Female	**Male**
1	Abraka Gram. Sch.	Abraka	Ethiope E	23	28
2	Agbon Sec. Sch.	Isiokolo	Ethiope East	22	29
3	Agbon College	Okpara-Inland	Ethiope East	32	19
4	Egbo Commercial Sec. Sch.	Egbo-Kokori	Ethiope East	40	11
5	Ekpan-Ovu Sec. Sch.	Ekpan-Ovu	Ethiope East	24	27
6	Eku Girls Sec. Sch.	Eku	Ethiope East	35	16
7	Erho Sec. Sch.	Erho-Abraka	Ethiope East	21	30
8	Ibruvwe Sec. Sch.	Samagidi-Kokori	Ethiope East	28	23
9	Igun Sec. Sch.	Igun	Ethiope East	15	35
10	Isiokolo Girls Sec. Sch.	Isiokolo	Ethiope East	31	20
11	Kokori Mixed Sec. School	Kokori	Ethiope East	28	23
12	Kokori Girls Sec. Sch.	Kokori-Inland	Ethiope East	20	31
13	Okpara Boys Sec. Sch.	Okpara-Inland	Ethiope East	35	16
14	Okpara Mixed Sec. Sch.	Okpara-Waterside	Ethiope East	39	12
15	Okurekpo Sec. Sch.	Okurekpo	Ethiope East	41	10
16	Orhoakpo Sec. Sch.	Orhoakpo	Ethiope East	27	23
17	Ojeta Sec. Sch.	Ekrejeta	Ethiope East	17	33
18	Otorho Sec. Sch.	Otorho-Abraka	Ethiope East	40	11
19	Oviorie Sec. Sch.	Oviorie	Ethiope East	17	23
20	Ovu Gram. Sch.	Ovu-Inland	Ethiope East	20	40

21	Ovu College	Urhodo-Ovu	Ethiope East	31	20
22	Owhere Gram. Sch.	Okpara-Waterside	Ethiope East	30	20
23	Umiaghwa Sec. Sch.	Oria-Abraka	Ethiope East	16	34
24	Urhuoka Sec. Sch.	Urhuoka-Abraka	Ethiope East	22	28
25	Baptist Med. Centre Staff Sec. Sch.	Eku	Ethiope East	29	21
26	Boboruku Sec. Sch.	Boboruku	Ethiope West	33	17
27	Idjerhe Sec. Sch.	Jesse	Ethiope West	40	11
28	Ighoyota Sec. Sch.	Ugbokpa-Mosogar	Ethiope West	31	20
29	Irhodo Sec. Sch.	Irhodo-Jesse	Ethiope West	29	22
30	Mosogar Sec. Sch.	Mosogar	Ethiope West	21	29
31	Ogharefe Sec. Sch.	Oghara-Junction	Ethiope West	19	31
32	Ogini Gram. Sch.	Ogharefe	Ethiope West	33	17
33	Okunigho Sec. Sch.	Okunigho	Ethiope West	25	26
34	Onyobru Sec. Sch.	Onyobru	Ethiope West	23	27
35	Orefe Sec. School	Ogharefe	Ethiope West	24	26
36	Oreki Sec. Sch.	Oghareki	Ethiope West	21	29
37	Osoguo Sec. Sch.	Osoguo	Ethiope West	19	31
38	Ovade Sec. Sch.	Ovade	Ethiope West	22	29
39	Toborise Basic Sch.	Ebughweri	Ethiope West	31	19
40	Uduaka Sec. Sch.	Mosogar	Ethiope West	25	26
41	Udurhie Sec. Sch.	Mosogar	Ethiope West	31	20
42	Ugbenu Sec. Sch.	Ugbenu	Ethiope West	23	27
43	Ugbevwe Sec. Sch.	Ugbevwe	Ethiope West	24	26
44	Ukavbe Sec. Sch.	Otefe	Ethiope	34	16

			West		
45	Ejera Sec. Sch.	Okono	Ethiope West	17	33
46	Oghareki Grammar School	Oghareki	Ethiope West	32	18
47	Jesse Secondary School	Jesse	Ethiope West	31	19
48	Ihwighwu Secondary School	Ijomi	Ethiope West	32	18
49	Osubi Sec. Sch.	Osubi	Okpe	20	30
50	Oyenke Sec. Sch.	Oyenke	Okpe	15	35
51	Adeje Sec. Sch.	Adeje	Okpe	25	27
52	Aghalokpe Mixed Sec. Sch.	Aghalokpe	Okpe	31	20
53	Arhagba Sec. Sch.	Arhagba	Okpe	30	20
54	Egborode Sec. Sch.	Egborode	Okpe	15	30
55	Eradajaye Sec. Sch.	Adagbrasa-Ugolo	Okpe	33	17
56	Esezi Sec. Sch.	Ughoton	Okpe	26	14
57	Jeddo Sec. Sch.	Jeddo	Okpe	25	25
58	Oha Sec. Sch.	Oha	Okpe	33	17
59	Okene Mixed Sec. Sch.	Okuokoko	Okpe	25	19
60	Okuovo Basic Sch.	Okuovo	Okpe	29	22
61	Orerokpe Sec. Sch.	Orerokpe	Okpe	31	30
62	Orhue Sec. Sch.	Mereje	Okpe	23	27
63	Oviri-Okpe Sec. Sch.	Oviri-Okpe	Okpe	17	33
64	Ugbokodo Sec. Sch.	Ugbokodo	Okpe	30	20
65	Adaka Gram. Sch.	Ugborhen	Sapele	24	11
66	Chude Girls Model Sec. Sch.	Sapele	Sapele	25	12
67	Elume Gram. Sch.	Elume	Sapele	13	27
68	Ethiope Mixed Sec. Sch.	Sapele	Sapele	22	38
69	Eziafa Sec. Sch.	Eziafa	Sapele	31	18
70	Gana Sec. Sch.	Sapele	Sapele	34	14
71	Ibada Seconadry Sch.	Ibada-Elume	Sapele	23	27
72	Ogiedi Mixed Sec. Sch.	Ogiedi-Elume	Sapele	13	28
73	Okotie-Eboh Gram. Sch.	Sapele	Sapele	35	14
74	Okpe Gram. Sch.	Sapele	Sapele	38	22
75	Orodje Gram. Sch.	Sapele	Sapele	23	27
76	Ozue Sec. Sch.	Okuovo Sapele	Sapele	31	20
77	Ufuoma Mixed Sec. Sch.	Sapele	Sapele	26	24
78	Urhiapele Mixed Sec. Sch.	Sapele	Sapele	23	27
79	Zik Sec. Sch.	Sapele	Sapele	32	20
80	Sapele Technical College	Sapele	Sapele	21	39
81	Okpaka Sec. Sch.	Okpakpa	Udu	13	27
82	Adadja Sec. Sch.	Emadadja	Udu	32	11

83	Aladja Sec. Sch.	Aladja	Udu	13	37
84	Egini Gram. Sch.	Egini	Udu	23	28
85	Ekete Sec. Sch.	Ekete	Udu	31	19
86	Ogbe-Udu Sec. Sch.	Ogbe-Udu	Udu	31	20
87	Oghior Sec. Sch.	Oghior	Udu	25	26
88	Oleri Sec. Sch.	Oleri	Udu	42	8
89	Orhuwhorun High Sch.	Orhuwhorun	Udu	32	10
90	Otor-Udu Sec. Sch.	Udu	Udu	21	29
91	Ovwian Sec. Sch.	Ovwian	Udu	17	17
92	Owhrode Mixed Sec. Sch.	Owhrode	Udu	24	34
93	Ubogo Sec. Sch.	Ubogo	Udu	22	31
94	Ujevwu Secondary Sch.	Ujevwu	Udu	32	18
95	Adagwe Sec. Sch.	Eruemukohwarien	Ughelli North	22	28
96	Afiesere Sec. Sch.	Afiesere	Ughelli North	23	27
97	Agadama Sec. Sch.	Agadama	Ughelli North	18	27
98	Aragba Sec. Sch.	Aragba-Orogun	Ughelli North	12	38
99	Awirhe Sec. Sch.	Awirhe-Agbarha	Ughelli North	23	27
100	Ebor Sec. Sch.	Ebor-Orogun	Ughelli North	21	30
101	Edjeba Sec. Sch.	Edjeba-Agbarha	Ughelli North	22	28
102	Edjekota Sec. Sch.	Edjekota	Ughelli North	12	28
103	Ehwerhe Gram. Sch.	Ehwerhe-Agbarho	Ughelli North	19	32
104	Ekiugbo Sec. Sch.	Ekiugbo	Ughelli North	35	17
105	Esejuvwewo Secondary School	Inene	Ughelli North	17	38
106	Oviri-Ogor Sec. Sch.	Oviri-Ogor	Ughelli North	28	18
107	Model Secondary School	Ughelli	Ughelli North	18	25
108	Ekredjebor Sec. Sch.	Ekredjebor-Ughelli	Ughelli North	16	34
109	Ekruopia Sec. Sch.	Obodeti-Orogun	Ughelli North	20	31
110	Emeragha Sec. Sch.	Emeragha	Ughelli North	32	18
111	Emonu Comp. High Sch.	Emonu-Orogun	Ughelli North	29	31

112	Eni Gram. Sch.	Evwreni	Ughelli North	25	26
113	Erhavwen Basic Sch.	Ekrerhavwen	Ughelli North	26	14
114	Girls Model Sec. School	Evwreni	Ughelli North	31	25
115	Government College	Ughelli	Ughelli North	14	26
116	Ibru College	Agbarha-Otor	Ughelli North	22	30
117	Ikweghwu Sec. Sch.	Ikweghwu-Agbarho	Ughelli North	19	30
118	Imodje Sec. Sch.	Imodje-Orogun	Ughelli North	33	17
119	Ofuoma Sec. Sch.	Ofuoma	Ughelli North	31	20
120	Ogbovwan Sec. Sch.	Ogbovwan	Ughelli North	39	11
121	Ogharha Sec. Sch.	Ogharha-Agbarha	Ughelli North	26	33
122	Oguname Basic Sch.	Oguname-Agbarho	Ughelli North	23	37
123	Oharisi Sec. Sch.	Ughelli	Ughelli North	26	30
124	Omo Sec. Sch.	Ovara-Orogun	Ughelli North	28	22
125	Orhoerha Sec. Sch.	Ugono-Orogun	Ughelli North	25	31
126	Orogun Gram. Sch.	Orogun	Ughelli North	22	29
127	Oteri Sec. Sch.	Oteri	Ughelli North	29	33
128	Otovwodo Gram. Sch.	Ughelli	Ughelli North	23	37
129	Owevwe Sec. Sch.	Ovwevwe	Ughelli North	31	21
130	Unenurhie Sec. Sch.	Unenurhie	Ughelli North	29	30
131	Unity Model Sec. Sch.	Agbarho	Ughelli North	29	11
132	Uvwiama Sec. Sch.	Uvwiama-Agbarho	Ughelli North	18	22
133	Uwheru Gram. Sch.	Uwheru	Ughelli North	18	31
134	Omavovwe Sec. Sch.	Omavovwe-Agbarha	Ughelli North	29	27
135	Ogor Technical College	Otogor	Ughelli	14	33

			North		
136	Ohoro Sec. Sch.	Ohoro-Uwheru	Ughelli North	23	31
137	Agbarho Grammar School	Agbarho	Ughelli North	39	12
138	Akperhe Sec. Sch.	Akperhe-Olomu	Ughelli South	37	9
139	Iwhreka Technical College	Iwhreka	Ughelli South	27	11
140	Ogele Secondary School	Iwhreka	Ughelli South	30	18
141	Assah Sec. School	Assah	Ughelli South	16	34
142	Arhavwarien Gram. Sch.	Arhavwarien	Ughelli South	19	29
143	Effurun-Otor Sec. Sch.	Effurun-Otor	Ughelli South	27	29
144	Egbo Sec. Sch.	Egbo-Uhurie	Ughelli South	17	34
145	Ewu Gram. Sch.	Ewu-Urhobo	Ughelli South	30	14
146	Gbaregolor Sec. Sch.	Gbaregolor	Ughelli South	12	38
147	Ofrukama Sec. Sch.	Ofrukama	Ughelli South	37	11
148	Oginibo Gram. Sch.	Oginibo	Ughelli South	29	22
149	Okparabe Sec. Sch.	Okparabe	Ughelli South	22	28
150	Okpare Sec. Sch.	Okpare	Ughelli South	14	33
151	Okuama Sec. Sch.	Okuama	Ughelli South	21	31
152	Olomu Sec. Sch.	Olomu	Ughelli South	28	27
153	Ophorigbala Sec. Sch.	Ophorigbala	Ughelli South	14	10
154	Orere Sec. Sch.	Orere	Ughelli South	15	19
155	Otokutu Sec. Sch.	Otokutu	Ughelli South	34	15
156	Otu-Jeremi Sec. Sch.	Otujeremi	Ughelli South	31	22
157	Oviri-Olomu Sec. Sch.	Oviri-Olomu	Ughelli South	18	39
158	Ovwor Sec. Sch.	Ovwor	Ughelli South	34	23

159	Owawha Sec. Sch.	Owawha	Ughelli South	32	19
160	Okwagbe Secondary School	Okwagbe	Ughelli South	38	12
161	Ughevwughe Sec. Sch.	Ughevwughe	Ughelli South	31	20
162	Ogbavweni Gram. School	Usiefrun	Ughelli South	41	10
163	Ekakpamre Gram. School	Ekakpamre	Ughelli South	37	11
164	Alegbon Sec. Sch.	Effurun	Uvwie	24	29
165	Army Day Sec. Sch. I	Effurun	Uvwie	36	13
166	Ebrumede Sec. Sch.	Ebrumede	Uvwie	25	29
167	Ekpan Sec. Sch.	Ekpan	Uvwie	34	17
168	Ekpan Basic Sch.	Ekpan	Uvwie	13	33
169	Iteregbi Sec. Sch.	Iteregbi	Uvwie	10	25
170	Ogbe Sec. Sch.	Effurun	Uvwie	39	18
171	Ohorhe Sec. Sch.	Ohorhe	Uvwie	36	11
172	Opete Sec. Sch.	Opete	Uvwie	33	17
173	Sedeco Basic Sch.	Enerhen	Uvwie	25	29
174	Ugbolokposo Sec. Sch.	Ugbolokposo	Uvwie	34	18
175	Ugbomro Sec. Sch.	Ugbomro	Uvwie	30	23
176	Ugborikoko Sec. Sch.	Ugborikoko	Uvwie	26	31
177	Urhobo Model College	Effurun	Uvwie	39	26
178	Abe I Sec. Sch.	Aruakpommah	Uvwie	12	38
179	Army Day Sec. Sch. II	Effurun	Uvwie	39	17
Total				4668	4277

Appendix I: Data Analysis Output

Research Question 1 and Hypothesis 1

Descriptives

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Pretest Problem-Solving	112	30	5	35	2245	20.04	7.244	52.475
Posttest Problem-Solving	112	55	25	80	5700	50.89	12.416	154.151
Pretest Discovery	103	30	5	35	2130	20.68	7.142	51.004
Posttest Discovery	103	50	25	75	4310	41.84	12.834	164.701
Pretest Lecture	101	30	5	35	2055	20.35	7.425	55.129
Posttest Lecture	101	30	25	55	3900	38.61	8.310	69.059
Valid N (listwise)	101							

ANOVA

Pretest

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21.634	2	10.817	.205	.815
Within Groups	16540.075	313	52.844		
Total	16561.709	315			

Homogeneous Subsets

Pretest

Scheffe[a,b]

Method	N	Subset for alpha = 0.05
		1
Problem-Solving	112	20.04
Lecture Method	101	20.35
Discovery Method	103	20.68
Sig.		.818

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 105.122.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

ANOVA

Posttest

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8729.717	2	4364.858	33.472	.000
Within Groups	40816.169	313	130.403		
Total	49545.886	315			

Multiple Comparison

Dependent Variable: Posttest

Scheffe

(I) Method	(J) Method	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Problem-Solving	Discovery Method	9.048*	1.559	.000	5.21	12.88
	Lecture Method	12.279*	1.567	.000	8.42	16.13
Discovery Method	Problem-Solving	-9.048*	1.559	.000	-12.88	-5.21
	Lecture Method	3.231	1.599	.132	-.70	7.16
Lecture Method	Problem-Solving	-12.279*	1.567	.000	-16.13	-8.42
	Discovery Method	-3.231	1.599	.132	-7.16	.70

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Posttest

Scheffe[a,b]

Method	N	Subset for alpha = 0.05	
		1	2
Lecture Method	101	38.61	
Discovery Method	103	41.84	
Problem-Solving	112		50.89
Sig.		.124	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 105.122.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Research Question 2 and Hypothesis 2

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Pretest Urban Discovery method	53	5	35	19.62	6.992
Pretest Rural Discovery method	50	5	35	21.80	7.197
Posttest Urban Discovery method	53	25	75	44.06	14.246
Posttest Rural Discovery Method	50	25	65	39.50	10.797
Valid N (listwise)	50				

T-Test

Group Statistics

	location	N	Mean	Std. Deviation	Std. Error Mean
	Urban	53	44.06	14.246	1.957
	Rural	50	39.50	10.797	1.527

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	3.496	.064	1.821	101	.072	4.557	2.502	-.406	9.520
Equal variances not assumed			1.836	96.599	.069	4.557	2.482	-.370	9.483

Research Question 3 and Hypothesis 3

Descriptives

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Pretest Urban Problem Solving	60	30	5	35	1215	20.25	6.853	46.970
Posttest Urban Problem Solving	60	35	35	70	3165	52.75	10.594	112.225
Pretest Rural Problem Solving	52	30	5	35	1030	19.81	7.731	59.766
Posttest Rural Problem solving	52	55	25	80	2535	48.75	14.033	196.936
Valid N (listwise)	52							

T-Test

Group Statistics

	location	N	Mean	Std. Deviation	Std. Error Mean
	Urban	60	52.75	10.594	1.368
	Rural	52	48.75	14.033	1.946

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	5.302	.023	1.715	110	.089	4.000	2.332	-.622	8.622
Equal variances not assumed			1.682	93.996	.096	4.000	2.379	-.723	8.723

Research Question 4 and hypothesis 4

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Male Pretest Discovery Method	46	5	35	970	21.09	7.296
Male Posttest Discovery method	46	25	65	1820	39.57	11.393
Female Pretest Discovery Method	57	5	35	1160	20.35	7.062
Female Posttest Discovery Method	57	25	75	2490	43.68	13.710
Valid N (listwise)	46					

T-Test

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
DpostGen	Male	46	39.57	11.393	1.680
	Female	57	43.68	13.710	1.816

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
DpostGen	Equal variances assumed	1.587	.211	-1.633	101	.106	-4.119	2.523	-9.124	.886
	Equal variances not assumed			-1.665	100.901	.099	-4.119	2.474	-9.026	.788

Research Questions 5 and Hypothesis 5

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Male Pretest Problem-Solving	49	5	35	20.61	7.334
Male Posttest ProbleSolving	49	25	75	53.67	11.893
Female Pretest Problem-Solving	63	5	35	19.60	7.201
Female Posttest Problemsolving	63	25	80	48.73	12.475
Valid N (listwise)	49				

T-Test

Group Statistics

	GenderP	N	Mean	Std. Deviation	Std. Error Mean
PpostGen	Male	49	53.67	11.893	1.699
	Female	63	48.73	12.475	1.572

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PpostGen	Equal variances assumed	.277	.600	2.123	110	.036	4.943	2.328	.329	9.558
	Equal variances not assumed			2.136	105.495	.035	4.943	2.314	.354	9.532

Research Question 6 and Hypothesis 6

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Method	316	1	3	1.97	.822
Male Pretest Problem-Solving	49	5	35	20.61	7.334
Female Pretest Problem-Solving	63	5	35	19.60	7.201
Male Posttest ProbleSolving	49	25	75	53.67	11.893
Female Posttest Problemsolving	63	25	80	48.73	12.475
Male Pretest Discovery Method	46	5	35	21.09	7.296
Female Pretest Discovery Method	57	5	35	20.35	7.062
Male Posttest Discovery method	46	25	65	39.57	11.393
Female Posttest Discovery Method	57	25	75	43.68	13.710
Male Pretest lecture	40	5	35	20.75	7.557
Female Pretest Lecture	61	5	35	20.08	7.388
Male Postest Lecture	40	25	55	38.12	8.373
Female Posttest Lecture	61	25	55	38.93	8.322
Valid N (listwise)	40				

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Method	1	Problem-Solving	112
	2	Discovery Method	103
	3	Lecture Method	101
Gender	1	Male	135
	2	Female	181

Descriptive Statistics

Dependent Variable: Posttest

Method	Gender	Mean	Std. Deviation	N
Problem-Solving	Male	53.67	11.893	49
	Female	48.73	12.475	63
	Total	50.89	12.416	112
Discovery Method	Male	39.57	11.393	46
	Female	43.68	13.710	57
	Total	41.84	12.834	103
Lecture Method	Male	38.12	8.373	40
	Female	38.93	8.322	61
	Total	38.61	8.310	101
Total	Male	44.26	12.879	135
	Female	43.84	12.317	181
	Total	44.02	12.541	316

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Posttest

F	df1	df2	Sig.
4.014	5	310	.002

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Pre + Meth + Gender + Meth * Gender

Tests of Between-Subjects Effects

Dependent Variable: Posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10232.264[a]	6	1705.377	13.404	.000
Intercept	77078.368	1	77078.368	605.826	.000
Pre	381.299	1	381.299	2.997	.084
Meth	9080.411	2	4540.205	35.685	.000
Gender	1.243	1	1.243	.010	.921
Meth * Gender	1130.827	2	565.414	4.444	.013
Error	39313.622	309	127.229		
Total	661850.000	316			
Corrected Total	49545.886	315			

a. R Squared = .207 (Adjusted R Squared = .191)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: Posttest

		95% Confidence Interval	
Mean	Std. Error	Lower Bound	Upper Bound
43.795[a]	.643	42.530	45.061

a. Covariates appearing in the model are evaluated at the following values: Pretest = 20.35.

2. Method

Estimates

Dependent Variable: Posttest

			95% Confidence Interval	
Method	Mean	Std. Error	Lower Bound	Upper Bound
Problem-Solving	51.165[a]	1.074	49.051	53.279
Discovery Method	41.681[a]	1.118	39.481	43.882
Lecture Method	38.540[a]	1.147	36.282	40.798

a. Covariates appearing in the model are evaluated at the following values: Pretest = 20.35.

Pairwise Comparisons

Dependent Variable: Posttest

(I) Method	(J) Method	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Problem-Solving	Discovery Method	9.484*	1.551	.000	6.432	12.536
	Lecture Method	12.625*	1.572	.000	9.532	15.718
Discovery Method	Problem-Solving	-9.484*	1.551	.000	-12.536	-6.432
	Lecture Method	3.141	1.602	.051	-.011	6.294
Lecture Method	Problem-Solving	-12.625*	1.572	.000	-15.718	-9.532
	Discovery Method	-3.141	1.602	.051	-6.294	.011

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: Posttest

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	9080.411	2	4540.205	35.685	.000
Error	39313.622	309	127.229		

The F tests the effect of Method. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

3. Gender

Estimates

Dependent Variable: Posttest

Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	43.859[a]	.975	41.940	45.778
Female	43.732[a]	.840	42.080	45.384

a. Covariates appearing in the model are evaluated at the following values: Pretest = 20.35.

Pairwise Comparisons

Dependent Variable: Posttest

(I) Gender	(J) Gender	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Male	Female	.127	1.288	.921	-2.407	2.661
Female	Male	-.127	1.288	.921	-2.661	2.407

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: Posttest

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	1.243	1	1.243	.010	.921
Error	39313.622	309	127.229		

The F tests the effect of Gender. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

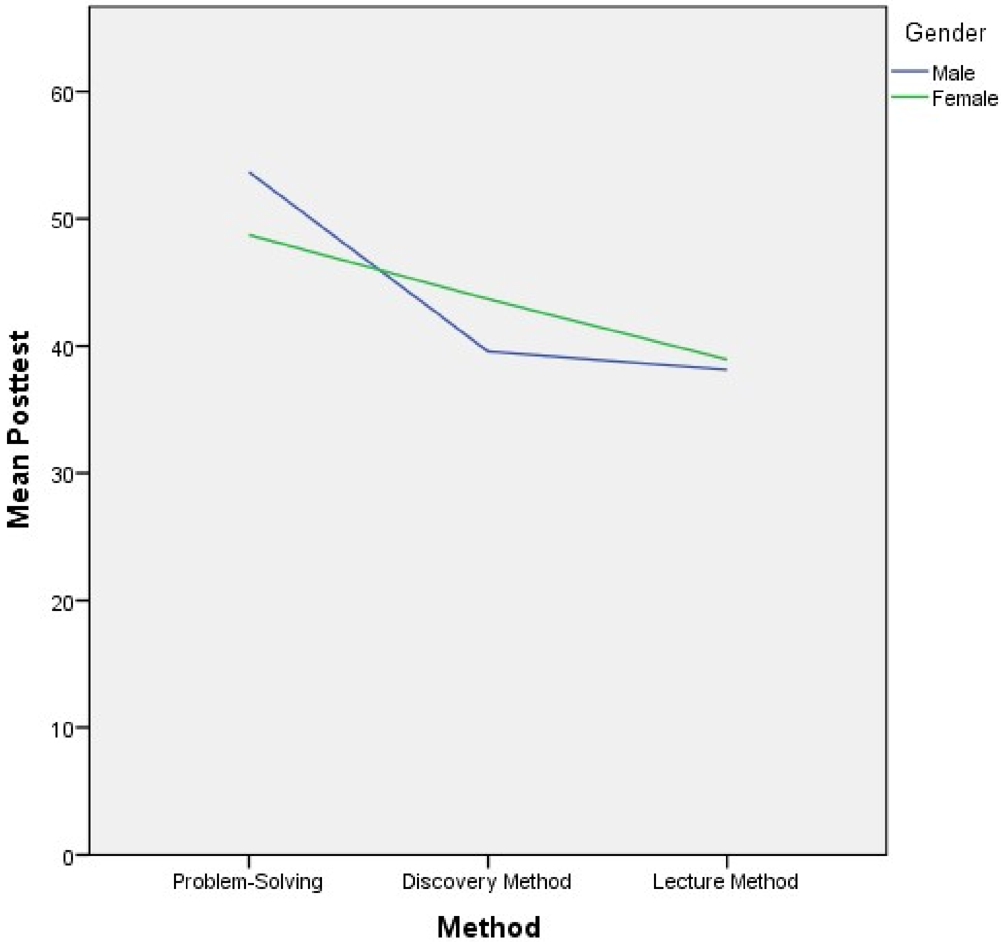
4. Method * Gender

Dependent Variable: Posttest

Method	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Problem-Solving	Male	53.714[a]	1.612	50.543	56.885
	Female	48.617[a]	1.423	45.818	51.416
Discovery Method	Male	39.678[a]	1.664	36.403	42.952
	Female	43.685[a]	1.494	40.745	46.624
Lecture Method	Male	38.186[a]	1.784	34.676	41.696
	Female	38.894[a]	1.444	36.052	41.736

a. Covariates appearing in the model are evaluated at the following values: Pretest = 20.35.

GGraph


Gender
Male
Female
60
50
40
30
20
10
0
Mean Posttest
Problem-Solving
Discovery Method
Lecture Method
Method

Research Question 7 and Hypothesis 7

Descriptives

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Pretest Urban Problem Solving	60	30	5	35	20.25	.885	6.853	46.970
Pretest Rural Problem Solving	52	30	5	35	19.81	1.072	7.731	59.766
Posttest Urban Problem Solving	60	35	35	70	52.75	1.368	10.594	112.225
Posttest Rural Problem solving	52	55	25	80	48.75	1.946	14.033	196.936
Pretest Urban Discovery method	53	30	5	35	19.62	.960	6.992	48.893
Pretest Rural Discovery method	50	30	5	35	21.80	1.018	7.197	51.796
Posttest Urban Discovery method	53	50	25	75	44.06	1.957	14.246	202.939
Posttest Rural Discovery Method	50	40	25	65	39.50	1.527	10.797	116.582
Pretest Urban Lecture	51	30	5	35	20.88	1.036	7.396	54.706
Pretest Rural lecture	50	30	5	35	19.80	1.059	7.489	56.082
Posttest Urban lecture	51	30	25	55	37.94	1.139	8.135	66.176
posttest Rural lecture	50	30	25	55	39.30	1.204	8.512	72.459
Valid N (listwise)	50							

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Method	1	Problem-Solving	112
	2	Discovery Method	103
	3	Lecture Method	101
Location	1	Urban	164
	2	Rural	152

Descriptive Statistics

Dependent Variable: Posttest

Method	Location	Mean	Std. Deviation	N
Problem-Solving	Urban	52.75	10.594	60
	Rural	48.75	14.033	52
	Total	50.89	12.416	112
Discovery Method	Urban	44.06	14.246	53
	Rural	39.50	10.797	50
	Total	41.84	12.834	103
Lecture Method	Urban	37.94	8.135	51
	Rural	39.30	8.512	50
	Total	38.61	8.310	101
Total	Urban	45.34	12.788	164
	Rural	42.60	12.152	152
	Total	44.02	12.541	316

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Posttest

F	df1	df2	Sig.
6.170	5	310	.000

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Pre + Meth + Location + Meth * Location

Tests of Between-Subjects Effects

Dependent Variable: Posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10056.235[a]	6	1676.039	13.115	.000
Intercept	75827.414	1	75827.414	593.337	.000
Pre	300.002	1	300.002	2.347	.127
Meth	8414.100	2	4207.050	32.919	.000
Location	441.825	1	441.825	3.457	.064
Meth * Location	493.293	2	246.647	1.930	.147
Error	39489.651	309	127.798		
Total	661850.000	316			
Corrected Total	49545.886	315			

a. R Squared = .203 (Adjusted R Squared = .187)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: Posttest

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
43.718[a]	.637	42.464	44.972

a. Covariates appearing in the model are evaluated at the following values: Pretest = 20.35.

2. Method

Estimates

Dependent Variable: Posttest

Method	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Problem-Solving	50.707[a]	1.071	48.599	52.815
Discovery Method	41.827[a]	1.115	39.634	44.021
Lecture Method	38.620[a]	1.125	36.406	40.833

a. Covariates appearing in the model are evaluated at the following values: Pretest = 20.35.

Pairwise Comparisons

Dependent Variable: Posttest

(I) Method	(J) Method	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Problem-Solving	Discovery Method	8.879*	1.547	.000	5.836	11.923
	Lecture Method	12.087*	1.553	.000	9.031	15.144
Discovery Method	Problem-Solving	-8.879*	1.547	.000	-11.923	-5.836
	Lecture Method	3.208*	1.584	.044	.091	6.324
Lecture Method	Problem-Solving	-12.087*	1.553	.000	-15.144	-9.031
	Discovery Method	-3.208*	1.584	.044	-6.324	-.091

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: Posttest

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	8414.100	2	4207.050	32.919	.000
Error	39489.651	309	127.798		

The F tests the effect of Method. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

3. Location

Estimates

Dependent Variable: Posttest

Location	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Urban	44.903[a]	.885	43.162	46.644
Rural	42.533[a]	.917	40.728	44.338

a. Covariates appearing in the model are evaluated at the following values: Pretest = 20.35.

Pairwise Comparisons

Dependent Variable: Posttest

(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Urban	Rural	2.370	1.275	.064	-.138	4.878
Rural	Urban	-2.370	1.275	.064	-4.878	.138

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: Posttest

	Sum of Squares	df	Mean Square	F	Sig.
Contrast	441.825	1	441.825	3.457	.064
Error	39489.651	309	127.798		

The F tests the effect of Location. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

4. Method * Location

Dependent Variable: Posttest

Method	Location	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Problem-Solving	Urban	52.737[a]	1.459	49.865	55.608
	Rural	48.677[a]	1.568	45.591	51.763
Discovery Method	Urban	43.958[a]	1.554	40.900	47.016
	Rural	39.696[a]	1.604	36.541	42.852
Lecture Method	Urban	38.013[a]	1.584	34.897	41.130
	Rural	39.226[a]	1.599	36.079	42.373

a. Covariates appearing in the model are evaluated at the following values: Pretest = 20.35.

Research Question 8 and Hypothesis 8

Descriptives

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Male Pretest Problem-Solving	49	5	35	20.61	7.334
Female Pretest Problem-Solving	63	5	35	19.60	7.201
Male Posttest ProbleSolving	49	25	75	53.67	11.893
Female Posttest Problemsolving	63	25	80	48.73	12.475
Male Pretest Discovery Method	46	5	35	21.09	7.296
Female Pretest Discovery Method	57	5	35	20.35	7.062
Male Posttest Discovery method	46	25	65	39.57	11.393
Female Posttest Discovery Method	57	25	75	43.68	13.710
Pretest Urban Problem Solving	60	5	35	20.25	6.853
Pretest Rural Problem Solving	52	5	35	19.81	7.731
Posttest Urban Problem Solving	60	35	70	52.75	10.594
Posttest Rural Problem solving	52	25	80	48.75	14.033
Pretest Urban Discovery method	53	5	35	19.62	6.992
Pretest Rural Discovery method	50	5	35	21.80	7.197
Posttest Urban Discovery method	53	25	75	44.06	14.246
Posttest Rural Discovery Method	50	25	65	39.50	10.797
Male Pretest lecture	40	5	35	20.75	7.557
Female Pretest Lecture	61	5	35	20.08	7.388
Male Postest Lecture	40	25	55	38.12	8.373
Female Posttest Lecture	61	25	55	38.93	8.322
Pretest Urban Lecture	51	5	35	20.88	7.396
Pretest Rural lecture	50	5	35	19.80	7.489
Posttest Urban lecture	51	25	55	37.94	8.135
posttest Rural lecture	50	25	55	39.30	8.512
Valid N (listwise)	40				

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Gender	1	Male	135
	2	Female	181
Method	1	Problem-Solving	112
	2	Discovery Method	103
	3	Lecture Method	101
Location	1	Urban	164
	2	Rural	152

Tests of Between-Subjects Effects

Dependent Variable: Posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	11499.636[a]	12	958.303	7.632	.000
Intercept	75374.888	1	75374.888	600.285	.000
Pre	314.969	1	314.969	2.508	.114
Gender	10.560	1	10.560	.084	.772
Meth	8314.243	2	4157.122	33.107	.000
Location	453.270	1	453.270	3.610	.058
Meth * Gender	1130.827	2	565.414	4.444	.013
Gender * Location	102.744	1	102.744	.818	.366
Meth * Location	493.293	2	246.647	1.930	.147
Gender * Meth * Location	78.331	2	39.166	.312	.732
Error	38046.250	303	125.565		
Total	661850.000	316			
Corrected Total	49545.886	315			

a. R Squared = .232 (Adjusted R Squared = .202)