COGNITIVE ABILITIES AS PREDICTORS OF CHEMISTRY ACHIEVEMENT AMONG SECONDARY SCHOOL STUDENTS IN DELTA CENTRAL SENATORIAL DISTRICT

CHAPTER ONE

INTRODUCTION

Background of the Study

In Nigeria today, the quest for scientific and technological knowledge has led to increased emphasis in the study of science subjects, especially chemistry. In the secondary schools, the number of students that seat for sciences in Senior School Certificate Examination (SSCE) is on the increase. Of these science subjects, chemistry attracts a large number of candidates (Ibegbunam & Ngini, 2011). One of the cardinal objectives of chemistry syllabus as derived from National Policy on Education (FME, 2004) is to prepare students to acquire cognitive ability in the area of reasoning and scientific attitudes. The syllabus also placed emphasis on field study; guided discovering; laboratory techniques and skills coupled with conceptual thinking that require high level of cognitive ability. Therefore, the effective learning and need for developing the cognitive abilities of students is of great importance. The purpose of education is not merely to enable students to accumulate facts. A major goal is that by the time students graduate from school, they should be able to solve problems facing their societies and to achieve this goal successfully, there is need to develop students' cognitive abilities. Lawson (2009) noted that student who can reason sensibly perform perfectly well in chemistry as a science subject since science does not involve guess work. The learner must reason out solution to the problem. Carrying out experiments and drawing concrete conclusions concerning a particular problem in chemistry requires the use of cognitive abilities.

Science is, by its nature, more a way of thinking and an approach for acquiring new knowledge than the accumulation of scientific knowledge and its applications. Science teaching does not necessarily mean the dissemination of scientific information. A primary objective should be to develop students' rational powers which constitute the essence of the ability to think. There are certain cognitive abilities associated with science, especially, chemistry that students need to develop during their school years. These are mostly, but not exclusively, verbal, non-verbal and quantitative reasoning abilities that are essential tools for a lifetime of participation in society as a whole (American Association for the Advancement of Science, 2007).

There are a number of different cognitive abilities such as attention, memory, logic and reasoning, auditory processing, processing speed and visual processing skills and among others. Some people are better at solving problems verbally while others are good at solving problems that involve visualization. Some people who are good at both of these problems may perform averagely at tasks that rely heavily on memory. The areas of cognitive abilities of interest in this study include verbal reasoning, quantitative reasoning and non-verbal reasoning abilities.

Verbal reasoning ability involves the skills and knowledge necessary to apply the use of verbal classification, sentence completion and verbal analogies to deal effectively with common problems and issues. Verbal reasoning ability reveals student’s ability to perceive the meaning of and relationships between words and word combinations. Quantitative reasoning ability involves the skills and knowledge necessary to apply the use of logic, numbers, and mathematics to deal effectively with common problems and issues. A student who is quantitatively literate can use numerical, geometric, and measurement data and concepts, mathematical skills, and principles of mathematical reasoning to draw logical conclusions and to make well-reasoned decisions. Non-verbal reasoning ability involves the skills and knowledge necessary to apply the use of figure classification, figure analogies and figure analysis to deal effectively with common problems and issues. Non-verbal ability indicates student's ability to spatially manipulate and reason with geometric patterns and figures. Students who score well in this area learn best through visuals pictures, objects, models simulation and hands-on activities. Studies have shown that helping students to develop cognitive abilities is a frequently cited goal of science educators (Ibegbuna & Ngini, 2011; Lawson, 2009). The National Science Teachers Association (NSTA) (2005) advocated that:

> science teachers should help students learn and think verbally and quantitatively, specifying that high school laboratory, discovery, inquiry and field activities for teaching and learning of chemistry should emphasize not only the acquisition of knowledge but also problem solving and decision making that involve critical reasoning.

In fact, science process skills taught in elementary grades such as observing, classifying and collecting data act as pre-requisites for the integrated processes usually taught in secondary school grade like hypothesizing, controlling variables and defining operationally (Tobin & Capie, 2009). Such processes require high level of verbal, quantitative and non-verbal reasoning abilities.

Verbal, non-verbal and quantitative reasoning abilities have been identified as essential abilities for success in advanced science and chemistry courses (Adey & Shayer, 2008). Some researchers reported significantly positive relationship between students' reasoning abilities and performance in science (Lawson, 2009 & Herron, 2008). There is a direct link between these three cognitive abilities (that is verbal, quantitative and non-verbal reasoning) and integrated processes of science such as identifying, controlling variables and hypothesizing. It is reported that cognitive ability was the strongest predictor of science process skill achievement and retention (Tobin and Capie, 2009).

On the other hand, researchers have indicated that there are no sex differences when it comes to verbal, non-verbal and quantitative reasoning abilities as they affect students' academic achievement (Valanides, 2010; Ibegbunam & Ngini, 2011). However, Halpern (2007) showed that males outperformed females in verbal and quantitative reasoning. Sex differences in non-verbal ability measures are not always favorable to females. Nevertheless, Hines (2010) found out that female outperformed male in non-verbal reasoning ability test. This shows that there is a controversy regarding sex differences in cognitive abilities as it affects academic achievement

While a considerable body of research exists focusing on the effect of several cognitive abilities on students' achievement in science subjects (Yilmaz & Alp, 2006; BouJaoude, Salloum & Khalick, 2004), relatively little is known about the effect of verbal reasoning, non-verbal reasoning and quantitative reasoning abilities on students' achievement in chemistry. Therefore, this study seeks to investigate cognitive abilities (that is, verbal, non-verbal and quantitative reasoning abilities) as predictors of chemistry achievement among secondary school students in Delta Central Senatorial District.

Statement of the Problem

Students' academic achievement is a major concern to school principals, school teachers, ministry of education officials, parents and the community at large. It is the desire of school instructors to see their students have a high academic performance. Consequently, several factors affecting students' academic achievement in chemistry have been identified over the years. Some of these factors include lack of motivation from examination results, lack of qualified science personnel and equipment, teacher related factors such as poor teaching methods, learner related factors such as misconception of some scientific concepts, home factors such as negative attitude of parents, effect of foreign language as a medium of instruction and frequent closure of schools. Other factors include school environment such as undesirable classroom environment; inappropriate medium of instruction, overloaded curriculum, admission of unqualified students and lack of training and retraining of personnel. Also, a crucial factor that can predict academic achievement of students remains an individual's level of reasoning ability. Measures of fluid intelligence (e.g. abstract reasoning and inductive reasoning), short term memory (e.g. digit span and block design), and working memory (e.g. computation span and dot matrix) are some cognitive factors that could predict academic achievement among secondary school students. But can one specifically say that verbal, non-verbal and quantitative reasoning abilities are also predictive of students' achievement in chemistry? Considering the fact that a number of factors affect students' academic achievement, this study therefore, intends to find out what cognitive abilities (that is, verbal reasoning, quantitative reasoning and non-verbal reasoning abilities) predict chemistry achievement among senior secondary school students?

Research Questions

The following research questions were raised to guide the study;

1. Is there any difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities?
2. Is there any difference in chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities?
3. Is there any difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities?
4. Is there any difference in chemistry achievement between male and female students with high verbal reasoning abilities?

5. Is there any difference in chemistry achievement between male and female students with high non-verbal reasoning abilities?
6. Is there any difference in chemistry achievement between male and female students with high quantitative reasoning abilities?
7. Is there any relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry?

Hypotheses

The following null hypotheses were formulated for testing at 0.05 level of significance.

$Ho_{1.}$ There is no significant difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities.

$Ho_{2.}$ There is no significant difference in chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities.

$Ho_{3.}$ There is no significant difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities.

$Ho_{4.}$ There is no significant difference in chemistry achievement between male and female students with high verbal reasoning abilities.

$Ho_{5.}$ There is no significant difference in chemistry achievement between male and female students with high non-verbal reasoning abilities.

$Ho_{6.}$ There is no significant difference in chemistry achievement between male and female students with high quantitative reasoning abilities.

$Ho_{7.}$ There is no significant relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry.

Purpose of the Study

The general purpose of the study is to investigate cognitive abilities (that is, verbal reasoning ability, quantitative reasoning ability and non-verbal reasoning ability) as predictors of chemistry achievement among secondary school students in Delta Central Senatorial District.

The specific purposes the study seeks to establish include:

1. if there is any difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities;
2. if there is any difference in chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities;

3. if there is any difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities;
4. if there is any difference in chemistry achievement between male and female students with high verbal reasoning abilities;
5. if there is any difference in chemistry achievement between male and female students with high non-verbal reasoning abilities;
6. if there is any difference in chemistry achievement between male and female students with high quantitative reasoning abilities; and
7. if there is any relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry.

Significance of the Study

This study was designed to determine cognitive abilities (that is verbal reasoning, quantitative reasoning and non-verbal reasoning abilities) as predictors of chemistry achievement among secondary school students. It also investigated sex differences in cognitive abilities as it relates to chemistry achievement. The study is therefore of significance to students, teachers, examination bodies, Ministry of Education officials and the community at large in the following ways-

The findings of the research may help the curriculum planners in the area of curriculum planning and development through ensuring that school curriculum is planned and developed with respect to the development of students cognitive abilities since these abilities may be necessary for the teaching and learning of chemistry.

The findings may help chemistry teachers on how best to teach considering the varying cognitive abilities of students. The findings of this study may be useful to the science classroom teacher in ensuring that they employ students' reasoning abilities in teaching.

The research findings may guide guidance counselors when assisting students on the issue of choosing subjects and career choices. Future researchers who would want to carry out similar research work may find the findings of this study very useful.

Another significance of the study is that the findings of this study may be useful in inspiring and motivating students to develop their reasoning abilities since there is a link between reasoning ability and science learning.

Scope and Delimitation of the Study

This study specifically determined cognitive abilities (verbal reasoning, quantitative reasoning and non-verbal reasoning abilities) as predictors of chemistry achievement among secondary school students. It also investigated the differences in cognitive abilities between sexes and the relationship between cognitive ability and chemistry achievement among secondary school students.

This study was limited to senior secondary schools (SS I) in Delta Central Senatorial District.

Limitations of the Study

The researcher was faced with many problems during the course of this study. Some of the students, especially in the rural schools were unable to read chemistry problems. Some of the teachers were not co-operative. Some of the teachers regularly interrupted the researcher during treatment.

Two of the research assistants that were trained by the researcher to assist the researcher during treatment relocated to other States. This increased the duration of treatment as the researcher had to train other research assistants to replace them.

Also, the study was restricted to only a few Senior Secondary Schools. Only 6 Senior Secondary Schools were selected for the study out of 178 Senior Secondary Schools in Delta Central Senatorial District due to distance between schools and the period for the study was short. Thus, it was not possible to carry out the study using all the Senior Secondary Schools in the Senatorial District.

Operational Definition of Terms

The terms and concepts that are commonly used in this study are hereby operationally defined as follows-

1. **Cognitive Abilities:** Cognitive abilities are the brain-based skills individuals need to carry out any task from the simplest to the most complex. They deal with the mechanisms of how students learn, remember, solve problem and pay attention rather than with any actual knowledge.
2. **Verbal Reasoning Ability:** This is a cognitive ability that involves the ability to perceive the meaning of / and relationships between words and word combinations.
3. **Quantitative Reasoning Ability:** This is a cognitive ability that involves the ability to comprehend and employ numbers, which permit one to understand relationships, computational rules, and problem-solving techniques.
4. **Non-verbal Reasoning Ability**: This is a cognitive ability that involves the ability to spatially manipulate and reason with geometric patterns and figures.
5. **Chemistry Achievement:** This is the attainments or scores in a test or examination.
6. **Reasoning Abilities:** It means the thinking skills which focuses on three factors; verbal reasoning, quantitative reasoning and non-verbal reasoning

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter reviewed related literature. The review is organized along the following sub-headings:

- Theoretical Framework of the Study
- The Cognitive Domain of Learning Objectives in Science Education
- The Concept of Reasoning Abilities
- Sex Difference in Cognitive Abilities
- The Need for Reasoning in Teaching and Learning of Science
- Measurement of Cognitive Abilities Using Reasoning Ability Tests
- Cognitive Factors and Academic Achievement
- Prediction Studies on Cognitive Factors and Academic Achievement
- Empirical Studies on Cognitive Abilities and Academic Achievement in Science
- Some Factors Affecting Students' Academic Performance in Chemistry
- Appraisal of the Review

Theoretical Framework of the Study

The theoretical framework is Bruner's theory of cognitive development: mode of representation. Bruner (1996) theorized that learning occurs by going through three stages of thinking and each stage is a way in which information is stored and encoded in memory. Each of Bruner's stages of representation builds up on the knowledge and information learned in the previous stage. In other words, the stage before acts as scaffolding for the next stage. The theory has come to play an important role in science education, particularly with the use of “manipulatives”. The stages are more-or-less sequential, although they are not necessarily age-related. The stages highlighted in his theory that relates to this study are:

1. Enactive (action-based): This stage is sometimes called the concrete stage. This first stage involves a tangible hands-on method of learning. Bruner believed that "learning begins with an action - touching, feeling and manipulating" In science education, “manipulatives” are the concrete objects with which actions are performed. Common examples of “manipulatives” used in this stage in chemistry education are microscopes, paper, etc. Bruner’s enactive (action-based) stage of thinking emphasizes learning through quantitative reasoning. Quantitative reasoning ability involves the skills and knowledge necessary to apply manipulative skills in the use of logic, numbers, mathematics and other physical materials to deal effectively with common problems and issues.

2. Iconic (image-based): This stage is sometimes called the pictoral stage. This second stage involves images or other visuals to represent the concrete situation enacted in the first stage. One way of doing this is to simply draw images of the objects on paper or to picture them in one's head. Other ways could be through the use of shapes, diagrams, and graphs. This stage is central to the development of students' non-verbal reasoning abilities. Non-verbal reasoning ability involves the skills and knowledge necessary to apply the use of figure classification, figure analogies and figure analysis to deal effectively with common problems and issues. Non-verbal ability indicates student's ability to spatially manipulate and reason with geometric patterns and figures. Bruner's Iconic (image-based) stage of thinking emphasizes that students learn through non-verbal reasoning.

3. Symbolic (language-based): This third and last stage is sometimes called the abstract stage. The stage takes the images from the second stage and represents those images using words and symbols. The use of words and symbols allows a student to organize information in his/her mind by relating concepts together. The words and symbols are abstractions and they do not necessarily have a direct connection to the information. For example, a number is a symbol used to describe how many of something there are, but the number in itself has little meaning without the understanding of what it means for there to be that number of something. Other examples would be variables such as x or y, or mathematical symbols such as +, -, /, etc. Finally, language and words are other ways to abstractly represent the idea. Bruner's Symbolic (language-based) stage of thinking emphasizes that students learn through verbal reasoning. Verbal reasoning ability involves the skills and knowledge necessary to apply the use of verbal classification, sentence completion and verbal analogies to deal effectively with common problems and issues. Verbal reasoning ability reveals student's ability to perceive the meaning of and relationships between words and word combinations. This is vital for learning of science, especially chemistry.

Bruner believed that all learning occurs through the stages highlighted above. The outcome of cognitive development is thinking (McLeod, 2008). While Bruner has influenced education greatly, it has been most noticeable in science education. The theory is useful in teaching science subjects such chemistry and mathematics which are primarily conceptual, as it begins with concrete representation and progresses to a more abstract one. Initially, the use of "manipulatives" in the enactive stage is a great way to "hook" students, who may not be particularly interested in the topic.

Furthermore, Bruner's theory allows teachers to be able to engage all students in the learning process regardless of their cognitive level. While more advanced students may have well-developed symbolic system and can successfully be taught at the symbolic level, other students may need other representations of problems to grasp the material (Brahier, 2009). In addition, by having all students go through each of the stages, it builds a foundation for which the student can fall back on if they forget or as they encounter increasingly difficult problems.

Another important part of the theory's application in science is the academic language. The development and use of an academic language is crucial for successfully learning of scientific concepts. This primarily takes place in transitioning from the iconic stage to the abstract, language-based symbolic stage. Since language is our primary means of symbolizing the world, Bruner attaches great importance to language in determining cognitive development (Mcleod, 2008). The correct academic language needs to be taught and used in the symbolic stage in order for students to demonstrate that they can not only come up with the correct answer but that they understand the problem and process for getting it. In this context, the academic language involves not only vocabulary and mathematical terms but also mathematical symbols.

According to Bruner (1996), the purpose of education is not to impart knowledge, but to facilitate a child's thinking and problem solving skills which can then be transferred to a range of situations. Specifically, education should also develop symbolic thinking in children. Thus, Bruner’s theory of three stages of thinking emphasizes the development of students’ cognitive abilities. The theory also emphasizes that learning takes place through the use of verbal, non-verbal and quantitative reasoning abilities. This forms the premise on which this study is based. Since, students learn through the use of verbal, non-verbal and quantitative reasoning abilities as described by Bruner's theory of cognitive development (mode of representation), chemistry can also be learned using these abilities.

The Cognitive Domain of Learning Objectives in Science Education

Children have the tendency to learn everything from everyone around them. The formal environment that children can learn most from is generally thought to be the school. Not only the academic skills but general life skills also can be learnt from school. Everything the children learn when they are young, will affect them when they grow up. Kail (2009) has suggested that effective comprehension in adults has been attributed to a fully matured working memory. Kail's suggestion shows that anything related to learning especially when people are young, will influence people's life when they grow up. Learning is often seen as a process of changing behaviour which occurs from either practice or experience. It is not a process of changing behaviour as a result of illness or maturation but it comes from the development of different types of cognitive abilities. Learning is a process of obtaining new knowledge, behavior, skills, values, preferences or understanding, and may involve combining different types of information. This is one aspect of the complexity of learning; that lots of different aspects are interrelated. Learning may occur consciously or without conscious awareness. So learning is a complex process.

Most educational objectives are of the cognitive domain in nature. The cognitive domain taxonomy has become the most widely used. The cognitive domain is divided into six major categories. These categories are further classified into two groups: Lower mental functions and higher mental functions. These govern the various specific objectives for teaching and testing students' ability. These categories are:

1. Knowledge: This is the recall of information. A specific generalization may constitute the recalled information. It should be emphasized that knowledge means recall only and not application of the information in a particular situation.
2. Comprehension: Understanding of the message of communication and the ability to explain or summarize it. This is where it is necessary for every learner to have a good command of the language in use. It involves explanation, estimating or predicting future trends, consequences or effects. Comprehension is the lowest level of understanding. At the end, teachers want pupils to understand facts, relate figures to situation, change figures to words, discuss what had been taught using their own words and giving examples that are very close and much more real to them. Specifically, at the end of a lesson students convert, defend, distinguish, estimate, explain,

extend, generalize, give examples, infer, paraphrase, predict, rewrite and summarize.

3. Application: The ability to use a principle, rule or method in a concrete situation. This is the ability to apply an existing physical situation to another. In a lesson plan, an aspect is referred to as application.
4. Analysis: This involves the ability to break down communication into constituent elements and to clarify its content. Here, concepts are formed; ideas are broken into related units and explained.
5. Synthesis: This is the ability to combine elements so as to form a whole. This category contains the notion of creativity which has in recent years been strongly emphasized as a worthwhile educational objective.
6. Evaluation: This is judging the value of materials and methods for a given purpose. This is where inferences are drawn for rational verdict.

The cognitive domain of learning objectives describes the order of thinking for students to perform steps from lower thinking skills to higher thinking skills; as we can see from the six categories above. The purpose of education, normally, is to improve students' skills especially cognitive abilities but it is difficult to evaluate because the thought is seen as a form of subjective behaviour. However, Bloom indicated these six steps into objective behaviour which can be examined relative to students' behaviour such as 'can a student remember X?' used for examining step one: knowledge acquisition. And higher to the highest ability; evaluation, step six, the behaviour that students have to perform in this step will be the assessment ability.

Many evaluation processes in Nigeria follow the stages of Bloom's taxonomy. Bloom's taxonomy can be seen as a description of thinking skills. Bloom (1956; cited in National Science Teachers Association (2005) declared that there are six categories of thinking skills. Marzano (1988) in National Science Teachers Association (2005) recommended eight skills that are important to learning process; (1) focusing skills, (2) information gathering skills, (3) remembering skills, (4) organizing skills, (5) analyzing skills, (6) generating skills, (7) integrating skills, and (8) evaluating skills. Both, Bloom's and Marzano's categories of thinking discuss the skills necessary for students development of cognitive abilities or showing of critical thinking skills which are very important for students to learn with extensive understanding.

The purpose of education is not merely to enable students to accumulate facts. A major goal is that by the time students graduate from school, they should be able to solve problems that are facing their societies. To achieve this goal successfully, there is need to develop students cognitive domain of learning which consequently enhances students verbal, Non-verbal and quantitative reasoning abilities. Lawson (2009) noted that student who can reason sensibly perform perfectly well in science courses because science does not involve guess work. The learner must reason out solution to the problem himself. This motivates students to carry out perfect experiment and draw concrete conclusions concerning a particular problem, hence this domain of learning objectives has a place in science education, especially in the study of chemistry within the context of students reasoning abilities.

The Concept of Reasoning Abilities

The concept of reasoning abilities is an interesting issue. In teaching students in school, there has been some attempt to change the way students think from cognitive lower-order skills to cognitive higher-order thinking skills. Ben-Chaim (2000) suggested that higher-order thinking skill development is essential to bring about the evolution of students' intelligence and abilities into sensible actions, no matter what their specific future roles in society will be. And Barak (2007) agreed with Ben-Chaim. He indicated further that the teaching of science should include not only the creating of student's knowledge capabilities but also the abilities of thinking, making decisions, and problem solving. The reason why teaching should include these abilities in school was explained more clearly by Angelo (2011) who said that critical thinking does not simply develop as a result of maturation, but involves skills that are notoriously difficult to teach and learn, the problem as to how to raise student's possible low critical thinking competency levels also deserves attention. Reasoning skills have been investigated by both psychologists and educators for a long time. In the early stage of investigation, they experimented on animals instead of humans.

Recently, Schmitt and Fischer (2009) conducted an experiment on inferential reasoning in Baboons by choosing a can of food. The results showed that the Baboons can use inferential reasoning the same as Apes and other old world monkeys. From this point of knowledge, it can be estimated that reasoning skills can be taught and be developed not just in animals but also in human beings. Reasoning is defined by Kirwin (2012) as the cognitive process of looking for reasons for beliefs, conclusions, actions or feelings. Reasoning skills are instruments for making decisions using specific cognitive skills, assessing skills and thinking systematically or abstractly (Crowell ,2009).

All of these researches confirmed that reasoning skills is important for life. Educators and educational psychologists can set a goal to determine the use of reasoning skills for improving learning and instruction in science education. For this reason, developmental and educational researchers should give precedence to reasoning skills because the results of the research may indicate the better way to train the science students to become more capable.

Sex Difference in Cognitive Abilities

There are hundreds of studies about sex differences in cognitive abilities (Halpern, 2007). The available number of databases facilitated several publications from which some robust conclusions have been extracted. Benbow and Stanley (1996) in their science publication said that;

> There is a major controversy concerning sex difference in quantitative reasoning ability. Pronounced sex differences in quantitative reasoning ability were observed among 9,927 intellectually talented 12 – 14 year olds. These students had taken the College Board Scholastic Aptitude Test, Quantitative (SAT-Q) and Verbal (SAT-V) several years before the typical age. The SAT-Q sex differences, favoring the boys, averaged 0.40 standard deviations.

Subsequently, Benbow and Stanley (1996) reported;

> Additional SAT data on 40,000 young adolescents. As discovered earlier, there was little difference between males and females in SAT-V scores, but male and female SAT-V distributions were found to be essentially equivalent, but male SAT-Q distribution manifested a higher mean and larger variance than was observed for the females. Consequently, an exponential intensification of the male - female ratio occurred in the upper tail of the combined distribution: The ratio was 2:1 for adolescents with SAT-Q scores of at least 500, 4:1 for those with scores of at least 600, and 13:1 for those with scores of at least 700.

Although various theories purport to explain these differences (Halpern, 2007), they are far from confirmed. Yet the differences themselves have been affirmed and noted in an American Psychological Association task force report “Intelligence: Knowns and Unknowns” (Neisser 1996)

Since Benbow and Stanley’s (1996) study, well over a million seventh and eighth graders have taken the SAT or American College Test (ACT) through annual talent searches (Benbow and Stanley, 1996; Van Tassel-Baska, 1996). Sex differences in SAT-Q score among intellectually talented 12 – 14 year-olds have persisted and are mirrored by those observed with the ACT-Q (Benbow & Stanley, 1996). In addition, Ablard and Stumpf (2008) presented data documenting sex differences in quantitative reasoning as early as the second grade (among intellectually gifted students), and Robinson , Abbott, Berninger and Busse (1996) reported sex differences in quantitative precocity before kindergarten. Moreover, these latter differences were maintained following mathematical enrichment opportunities. Indeed, boys gained more than girls did on quantitative and non-verbal measures after an average of 28 (bi-weekly) intervention sessions (Robinson, Abbott, Berninger, Busse & Mukhopadhya, 1997)

Given these robust and early-emerging sex differences in reasoning ability, it is critical to understand their long-term implications. Large –scale studies have revealed that sex differences in quantitative reasoning ability persist throughout high school (Hedges, 1995) and predict sex differences in reasoning abilities and science achievement at the end of high school and college (Benbow, 2009). In one large intellectually gifted sample, there were twice as many males as females pursuing engineering and physical science doctorates (Benbow, 2009). In general and irrespective of sex, students with tilted intellectual profiles tend to gravitate toward their area of strength. Those with exceptional quantitative reasoning ability relative to verbal ability tend to gravitate towards mathematics, engineering and physical sciences, while those with the inverse pattern are more attracted to the humanities, law and social sciences. The tilt in the math-physical sciences direction is especially pronounced for males, whereas the tilt toward humanities is stronger for females (Achter, Lubinski, Benbow & Eftekhari-Sanjani, 1999). Therefore, it is important to investigate the effect of cognitive abilities and sex differences in cognitive abilities on chemistry achievement among secondary school students.

The Need for Reasoning in Teaching and Learning of Science

One reason that humans especially at this time need reason is because of too much information distributed in this world and in a variety of ways, such as TV, radio, newspaper, or Internet. Not only is correct information given, incorrect information also comes to the public. It is a human responsibility to organize it, discriminate and make good decision. Making decisions, even big or small, is often difficult (Shafir & Tversky, 1995) because of conflict and uncertainty related to specific situations and the associated emotions that are sometimes involved, including their experience. The idea is that rational decision making is a main ability and will enable people to reach their objective (Searle, 2014). Moreover, reasoning can be used for resolution of controversies. For example, academic controversy, which is the instructional use of intellectual conflict to encourage higher achievement and raise the quality of problem solving, decision making, critical thinking, reasoning, interpersonal relationships, and psychological health and wellbeing (Johnson, 2005). Some of the choices that human beings have to make include decisions that may include the career, whether or not to use alcohol, cigarettes, or other drugs, or whether or not to engage in violent or risky behaviours (Fischhoff et al., 1999; Ganzel, 1999). Concern about these risk behaviours, a programme involved with the development of reasoning skills is needed to help teenagers better protect themselves with effective decision making skills.

Lastly, reasoning not only applies to making decisions but also aims at stating truths. Reasoning skills in relation to secondary school students have been a focus of interest for a long time. Johnson (2005) stated that when teaching science students, reasoning becomes more necessary and important. He recommended that when teaching science students informal reasoning, there is need to provide students with a model of reasoning which clearly specifies the skills to be learnt such as manage the skills into the rough order depending on the function and complexity; direct instruction of reasoning very well; provide more practice on reasoning; and give precise feedback. The aim of this is to teach students to analyze, evaluate, and construct informal arguments. Spurrett (2005) confirmed that the classes containing variety of talent, skill and motivation will need more creativity and dedication in the teaching process. However, it is a risk for some students that if they are left behind, they may think ineffectively. He suggested that it will be better if educators prepare the curriculum from the early stages of educational system to enable science students gain the skill and motivation at critical reasoning more effectively. This good preparation could help the students to be successful in other courses and the future.

Schmidt and Hunter (1998) concluded that reasoning ability tests are the best predictors of job performance. They also reported that reasoning ability tests can predict the effectiveness of staff training programmes, with staff that have higher levels of reasoning ability able to be trained more effectively than those who have lower levels of reasoning ability.

Hence, reasoning abilities are necessary in both school and work place. Students and workers who have higher reasoning abilities seem to have more efficiency than others. It would be better to prepare the curriculum to teach reasoning skills in school because students can develop and use such abilities when they grow up.

Measurement of Cognitive Abilities Using Reasoning Ability Tests

A test is an instrument to examine something such as knowledge, skills, aptitude, and so on of the test taker. Reasoning tests were first developed by Alfred Binet, a French educationalist who published the first test of mental ability in 1905. He was interested in assessing the intellectual development of children, and eventually he developed the concept of mental age. The reasoning test was a part of an IQ test; the Stanford-Binet intelligence scales can be considered the first one of all modern intelligence assessments. The Stanford-Binet scales have evolved through many revisions. The first one received analysis by Lewis Terman in 1916. Terman produced 'The Measurement of Intelligence: An Explanation of and a Complete Guide for the Use of the Stanford Revision and Extension of the Binet-Simon Intelligence Scale'. This guide presented translations and adaptations of the French items, plus new items that he had developed and tested between 1904 and 1915 as cited in Hyde (2011). Later this test was revised by many people such as Maud Merrill, in the 1950s, Thorndike, Hagen, and Sattler, in 1986. The tests were criticized because some were thought to be culturally biased –that they favoured upper classes. Also they were thought to test just one type of intelligence - logic. Gardner & Hatch (1989) in Hyde (2011) viewed intelligence as multiple intelligences. Hyde initially described seven types of intelligence: Spatial, Linguistic, Logical-mathematical, Bodily-kinesthetic, Musical, Interpersonal, and Intrapersonal that these would allow seven ways to teach rather than one. Hyde (2011) defined intelligence as 'the capacity to solve problems or to fashion products that are valued in one or more cultural setting'. This kind of thinking challenged some of the simple assumptions of the early test developers.

Reasoning ability test is a kind of psychological test which places emphasis on cognitive thinking and reasoning. Among many psychological tests, reasoning skills tests have been widely adopted. Newton and Bristoll (2010) conducted abstract reasoning test with diagrams, symbols and shapes instead of words and numbers. They suggested that the diagrams, symbols, and shapes do not involve ability in language and number which most reasoning test usually requires and may affect the test outcome. The University of Kent Careers Advisory Service (2008) has produced four types of reasoning test. They use these tests and others for helping people to consider a suitable career which employers can use together with interviews, application forms, references, academic results and other selection methods.

Cognitive ability test which was used for this research is an aptitude test that measures a student's general and specific cognitive abilities. This test measures learned reasoning and problem-solving skills in three areas: verbal reasoning, quantitative reasoning, and nonverbal reasoning. Verbal reasoning Score reveals the student's ability to perceive the meaning of and relationships between words and word combinations. Students are tested in this area by performing sentence completion, solving verbal analogies, and figuring out the relationships between the meanings of words. Quantitative reasoning score reveals the student's ability to comprehend and employ numbers that permit him to understand relationships, computational rules, and problem-solving techniques. This ability is tested through asking the student to build and solve equations, recognize number series, and demonstrate an understanding of the relationship between numbers and their values. Nonverbal reasoning score indicates the student's ability to spatially manipulate and reason with geometric patterns and figures. Students who score well in this area learn best through visuals--pictures, objects, models-simulations, and hands-on activities. Nonverbal abilities are determined from a student's ability to solve figure analogies, classify designs, and exercise skill in recognizing figures in dimension.

Shayer and Adey (2008) showed that instruction designed to develop cognitive abilities resulted in larger differences in science achievement between control and experimental groups when measured 1-3 years after instruction. For some experimental group students, the effects were carried over to mathematics and English achievements. Lawson (2009) argued that the best predicator of achievement depends on how achievement is defined and measured. It is in line with this that three cognitive abilities of verbal, non-verbal and quantitative reasoning abilities are chosen as the independent variables for this study and are measured using cognitive ability test.

Cognitive Factors and Academic Achievement

For many children, attainment of an education is associated with a better quality of life, longer life expectancy, and higher socioeconomic status (Chan, 2012). Success in science and some elementary subjects like reading and arithmetic depends on certain cognitive factors. Cognitive factors are a set of abilities that are learned to varying degrees as a person grows and develops mentally. They refer to skills that are used to learn, understand and integrate information in a meaningful way. There are many cognitive factors, and each broad category can be broken down into very specific sets of skills. Some examples of cognitive factors include memory, attention skills, visual spatial skills, logic and reasoning skills, intelligence, a wide category known as executive skills, etc. Memory which is the ability to store and recall information is needed when reading to decode unfamiliar words, retrieve semantic knowledge of familiar words, recall previously read text and anticipate where the passage is going (Cutting, 2009). Working memory is used during arithmetic for multi-digit calculations and for activating, retrieving, and manipulating information in long-term memory (Hitch, 1999). In performing calculations, visual spatial skills which is the ability to perceive, analyze, and think in visual images are also required to code the meaning of a digit in a multi-digit number (Deano, 2011). Intelligence which has to do with the ability to deal with cognitive complexity (Gottfredson, 1998) enhances the individual's understanding of concepts and causal relationships especially, in the area of science. It increases insight, foresight, and rationality. It leads to proximal consequences, such as higher quality of work and more reasonable decisions in everyday life. The child's attention skills also aid in reading and are associated with academic performance (Huizink, 2010). One of the most important categories of cognitive factors involves the executive functions. These are abilities that can help to govern other skills and provide a mental framework essential to learning. Executive functions include sequencing, inhibition, problem solving, flexibility, etc. Individual differences in academic achievement have been linked to differences in cognitive factors (Stumm, 2011). Students with higher cognitive factors tend to achieve highly in academic settings. A recent meta-analysis suggested that mental curiosity has an important influence on academic achievement (Stumm, 2011)

Cognitive factors that this study focuses on include verbal reasoning ability, non-verbal reasoning ability and quantitative reasoning ability. Verbal reasoning ability involves student's ability to perceive the meaning of and relationships between words and word combinations. Quantitative reasoning ability involves student's ability to comprehend and employ numbers that permit him to understand relationships, computational rules, and problem-solving techniques. Non-verbal reasoning ability indicates the student's ability to spatially manipulate and reason with geometric patterns and figures. These factors comprise students’ reasoning ability and reasoning abilities are necessary in both school and work place. Students and workers who have higher reasoning abilities seem to have more efficiency than others. It is expected that these reasoning abilities have a direct influence on academic achievement in chemistry.

Prediction Studies on Cognitive Factors and Academic Achievement

Cognitive factors are of central importance in predicting not only job performance, but also wealth and socio-economic success (Zagorsky, 2007), and job type (Gottfredson, 2003). For more than a century, psychologists and educationalists have been interested in the links between various tests of mental ability and academic performance. A crucial factor in predicting academic achievement remains an individual’s level of reasoning ability as demonstrated by several researchers (e.g. Colom, Escorial, Shih & Pivado, 2007) who demonstrated that measures of fluid intelligence (e.g. abstract reasoning and inductive reasoning), short term memory (e.g. digit span and block design), and working memory (e.g. computation span and dot matrix) were all predictive of academic performance among secondary school students.

Although it is clear that some lower order personality traits such as self-esteem, attributional style, and trait hope play important role in predicting academic achievement (Deary, 2007), it is also found that a number of cognitive factors help to shape an individual's academic performance (e.g. Ackerman & Heggestad, 1997; O'Connor & Paunonen, 2007). The personality and cognitive ability literatures have tended to develop independently, although there have been attempts at integration. Many studies are conducted with university students and it is still unclear how specific cognitive factors interact to influence school performance.

A longstanding central issue for the educational and differential psychologist is the prediction of academic achievement (e.g., Busato, Prins, Elshout & Hamaker, 2000). This issue has prompted the design and development of psychometric intelligence tests and, more specifically, cognitive ability tests (Robinson, 1999). As a consequence, the prediction of academic achievement has been largely associated with the construct and measurement of a person's intelligence. Although there is an extensive body of research in support of the inclusion of psychometric intelligence tests in the prediction of academic achievement (e.g., Gottfredson, 2003; Kuncel, Hezlett, & Ones, 2001; Zeidner &

Matthews, 2000; Brody, 2000;), recent research has suggested specifically that verbal, non-verbal and quantitative reasoning abilities may be equally effective in predicting academic performance, particularly at higher levels of formal education (Chamorro, Premuzic & Furnham, 2003a).

Further, there is a considerable amount of research suggesting that, particularly in university settings, the relation between psychometric intelligence and academic performance may be weaker than expected, and is often not significant (Singh & Varma, 2009), mainly because of the highly restrictive range of intelligence in the students and the increase in continuous assessment over examinations. It thus seems imperative to carry out this study in order to ascertain the effect of cognitive abilities of verbal, non-verbal and quantitative reasoning abilities on students' achievement in chemistry among secondary school students.

Empirical Studies on Cognitive Abilities and Academic Achievement in Science

One of the central purposes of cognitive ability testing, dating back to Alfred Binet, is to predict academic achievement (Binet & Simon, 1916; cited in Scot & Matthew, 2012). Researchers have shown a strong relationship between cognitive abilities and school grades in science subjects (e.g, Mackintosh, 2008). In a recent study, multiple measures of cognitive abilities were used to predict group administered standardized national public examination results across 25 academic subjects (Deary, 2007). Other studies have found that the average cognitive abilities of a nation is highly correlated with the academic achievement of that nation (Lynn & Meisenberg, 2010). Looking at differences in cognitive abilities across 86 countries, Lynn and Meisenberg (2010) found a correlation of 0.92 between a nation's measured cognitive abilities and the educational attainment of school students in science subjects and reading comprehension. A related issue is the extent to which the relation between Gustaffson and Balke (2003) investigated the relationship between cognitive abilities and school achievement comprising course grades in different science subjects. They found that cognitive abilities explained a substantial amount (40%) of the variance in academic achievement in science subjects.

Similarly, among a sample of German students, Rindermann and Neubauer (2004) found a correlation of 0.63 between cognitive abilities and academic achievement consisting of school grades in science subjects including chemistry. Although these studies provided important insights into the possible causal relations linking cognitive abilities to academic achievement in science, they did not directly measure the effect of verbal, non-verbal and quantitative reasoning abilities on chemistry achievements among secondary school students. This is why this study is on verbal, non-verbal and quantitative abilities as predictors of chemistry achievement among secondary school students.

Some Factors Affecting Students' Academic Performance in Chemistry

Chemistry is one of the most important branches of science. On the other hand chemistry proves a difficult subject for many students (Sirhan, 2007). Chemistry is a human endeavor that relies on basic human qualities like creativity, insights, reasoning, and skills (Banya, 2005). Chemistry is commonly viewed as the "central science", as mastery of its concepts regarding the structure of matter is essential to further coursework in all sciences. In essence, Chemistry performs the function of gatekeeper for future study in many sciences (Tai, Sadler & Loehr, 2005). The important goals of science education in different educational systems all over the world include

I. The effective use of scientific information in basic science and the transmission of knowledge to senior secondary school, college and university students.
II. The cultivation of the habit of applying the scientific method for the discovery of the concept of "learning how to learn".
III. The familiarity with the correct inquiry methods.
IV. The principles of dealing with problems and problem solving.

Therefore, the teaching and learning of chemistry in schools is very important and the following factors affect students' achievement in chemistry.

1. Motivation in learning Chemistry**:** Chemical education reform is under way in many countries. An important reason for this reform is the growing dissatisfaction with the position of many Chemistry curricula: quite isolated from students' personal interest, from current society and technology issues, and from modern Chemistry (Jong, 2006). According to Holbrook (2005), the stress on conception, understanding and appreciation for the nature of science (especially in the area of chemistry) tends not to be relevant for functionality in our lives i.e. relevant to the home, the environment, future employment and most definitely for future changes and developments within the society. Rensnik (1987; cited in Sirhan, (2007) found that students will engage more easily with problems that are embedded in challenging real-world contexts that have apparent relevance to their lives. If the problems are interesting, meaningful, challenging, and engaging they tend to be intrinsically motivating for students. Motivation to learn is an important factor controlling the success of learning and teachers face problems when their students do not have the motivation to seek to understand (Sirhan, 2007). According to Akbas and Kan (2007) motivation and anxiety affect many other factors such as the will and the interests of students in lessons. Thus, it could be thought that students'

performances would be affected. Studies have shown that attitude toward learning of chemistry influences behaviors like course selection, science field trips, and the continuation with science studies (Koballa & Crowley, 1985; cited in Banye, (2005). Berg (2005) found in a research a positive attitude change was associated with evidence of motivated behavior, while a negative change was linked to less motivated behavior. Jurisevic, Glazer, Pucko and Devetak (2008) reported that students were more or less equally motivated for chemistry as for any other subject, but that the intrinsic motivation plummets as the level of obstruction in individual subjects, such as chemistry and mathematics, increases. Also, it was found out that the motivation and anxiety for chemistry lesson, on their own, is a significant predictor of chemistry achievement. The anxiety caused by excessive stress has adverse effects on learning and performance of students (Akbas & Kan, 2007). Anders and Berg (2005) found that the more students were motivated, the more positive change was observed in their attitude toward learning chemistry.

2. Previous experiences: It is vital for the chemistry teacher to know what the learners already know and how they came to acquire the knowledge (Sirhan, 2007). According to Tai, Sadler, and Loehr (2005) there is need to identify pedagogical practices in science classrooms that connect to subsequent success in science learning. This influential links between science teaching in high

school and science success in college may be beneficial in efforts to improve science performance.

3. Teaching methods: There is need to embrace relevant teaching approaches to the teaching of chemistry in schools (Holbrook, 2005). Sirhan (2007) reported that attitudes and motivation are both important aspects for the learning process. Success in learning, positive attitudes to learning and motivation to learn are linked and are dependent on teaching methods. The two major factors influencing attitudes towards a subject are teacher quality and curriculum quality. According to Weiss, Pasely, Smit, Banilowel, and Heck (2003; cited in Tai, Sadler & Loehr, (2005), the greatest influence on the choice regarding instructional strategies is teacher knowledge, belief, and experience, influencing ninety percent of lessons taught by the teachers. Karr, Makher and Son (2006) consider that teaching method of teaching chemistry is based on the facilitation of the students' understanding in the learning process. An instructor makes much effort to cause his or her students to comprehend the subject matter. An instructor also tries to cause the students to be involved in the teaching and learning process so that he or she might become sure of this fact that the students are able to reproduce the knowledge and reasons of chemistry. An instructor expects the students to learn what he or she has taught and apply them in the future. Wachanga and Mwangi (2004) found that cooperative class

experiment teaching method caused facilitation in learning of chemistry. Okey and Butts (1983; cited in Wachanga & Mwangi, (2004) in their analysis of several studies found focusing discussions, making students aware of objectives, frequent feedback from students, students physical interaction with materials, a wide range of activities for students and longer wait-time all enhanced achievement of instructional objectives. Anderson (2007) in a consolidation of meta-analysis concluded that there is evidence supporting the use of inquiry teaching towards greater student achievement. However, the use of multiple teaching strategies including inquiry teaching should be adopted by all teachers in order to meet different learning styles in the classroom.

4. Science Laboratories: Wong and Fraser (1996) found significant association between science laboratories and students' academic achievement. Tai, Sadler and Loehr (2005) found out that several interesting high school pedagogical experiences linked with varying laboratory work was associated with higher student grades. Meanwhile, overemphasis on laboratory procedure in high school chemistry was associated with lower grades in college. These results suggest that the use of laboratories in the learning of chemistry may have a link to future student performance. Students reporting more instances of repeating laboratory work to enhance their understanding earned higher chemistry grades than their peers who reported few or no instances of repeating laboratory work

for understanding (Tai, Sadler & Loehr, 2005). Tai, et al (2005) say that laboratory work holds greater promise in helping to prepare students for college-level studies.

5. Instructional materials: The necessity for the use of instructional materials in the teaching and learning process cannot be overemphasized. When instructional materials are properly used in teaching and learning process, they help to concretized abstract concepts and put the elements of reality into ideas that may seem impracticable. It is also believed that they help the learner's memory such that he or she easily recollects what he/she was taught when the idea is needed.

6. Sex: Sex studies have indicated that attitudes toward science education (especially chemistry) differ between males and females. A declining interest in chemistry and the under representation of females in the chemical science was found (Jacobs, 2000; cited in Banya, 2005). Self -confidence toward chemistry, the influence of role models, and knowledge about the usefulness of chemistry affect the decision of young female students in learning of chemistry (Banya, 2005). For example, when young female students find difficulty in constructing knowledge of chemistry, self-confidence is lowered and this subsequently affects their attitudes toward chemistry (Banya, 2005). The attitudes of young female students toward science and chemistry are still positive (Banya, 2005).

Some schools of thought feel that sex difference have to do with cognitive abilities

7. Examination malpractice: Examination malpractice is cheating in the examination or any intention to benefit or give undue advantage to oneself or another by deceit or fraud, before, during and after examination. Examination malpractice is already becoming a culture in the Nigerian educational scene. This is because the ugly face of examination malpractice is been acknowledged by most parents, students, teachers and even lecturers. Sequel to the frequent cases of examination malpractice, the society is almost losing faith in the entry grades and certificates awarded by some institutions and examination bodies.

Research literature reported that students in Nigeria do not perform well in the sciences especially chemistry (Ogunleye, 1999). The problem of underachievement and low enrolment in sciences are not limited to Nigeria. The question we may want to ask is, ‘why are our students performing woefully in the sciences’? The following factors were recognized through empirical researches

1. Lack of motivation from examination results
2. Lack of qualified science personnel and equipment
3. Teacher related factors such as poor teaching methods
4. Learner related factors such as misconception of some scientific concepts

5. Home factors such as negative attitude of parents
6. Adverse effect of foreign language as a medium of instruction
7. Frequent closure of schools
8. School environment factors such as undesirable classroom environment; inappropriate medium of instruction, overloaded curriculum, admission of unqualified students and lack of training and retraining of personnel
9. Poor classroom management

According to Raimi (2002), despite the fact that the present science curricula recommended the teaching and acquisition of science process skills, most secondary school teachers often pay little attention to practical work. He further reported that from personal observation, when practical lessons are held by teachers, they are usually held too close to the final examination period, especially WAEC and NECO examinations.

In order to bail our students out of the poor achievement in science, new methods of instruction have been advocated. These include co-operative and competitive or individualistic learning, problem solving technique, framing and team-assisted instruction, peer tutoring and explicit teaching, focusing discussions, inquiry teaching and many others which enable students to use their cognitive abilities.

A major focus of science instruction over the years has been the development of achievement in science courses. At various times during the history of science education, terms such as problem solving, scientific thinking, and formal reasoning abilities have been used to describe student cognitive abilities. These terms reflect similar kind of thinking in science. This can be seen when a student attempts to solve a scientific problem through the use of verbal, non-verbal and quantitative reasoning abilities. During the past decade, researchers (Adey & Shayer, 2008) in science education have brought to light the importance of the cognitive factors influencing achievement in science courses especially the area of chemistry. Many of the concepts traditional1y covered in high school chemistry are of highly abstract entities and require students reasoning abilities to understand concepts and principles (Adey & Shayer, 2008). Therefore, verbal, non-verbal and quantitative reasoning abilities are major factors that influence students' performance in chemistry.

Appraisal of the Review

The review of literature revealed that cognitive factors are of central importance in predicting not only job performance, but also wealth, socio-economic success and job type. The review of literature revealed that a crucial factor that can predict academic achievement of students remains an individual's level of reasoning ability as demonstrated by several researchers (e.g. Colom, Escorial, Shih & Pivado, 2007). From the review of literature, measures of fluid intelligence (e.g. abstract reasoning and inductive reasoning), short term memory (e.g. digit span and block design), and working memory (e.g. computation span and dot matrix) are some cognitive factors that were predictive of academic achievement among secondary school students. Thus, the literature revealed that a number of cognitive factors help to shape an individual’s academic achievement. Other studies have shown that the average cognitive ability of a nation is highly correlated with the academic achievement of that nation. Researchers have shown a strong relationship between cognitive abilities and school grades in science subjects. Multiple measures of cognitive abilities were used to predict group administered standardized national public examination results across 25 academic subjects. Students’ academic achievement has been largely associated with the construct and measurement of a person’s intelligence. Other researchers found that cognitive abilities explained a substantial amount (40%) of the variance in academic achievement in science subjects. Although these studies provided important insights into the possible causal relations linking cognitive abilities to academic achievement in science, they did not directly measure verbal, non-verbal and quantitative reasoning abilities as predictors of chemistry achievements among secondary school students in Delta Central Senatorial District. It thus seemed imperative to carry out this study in order to ascertain cognitive abilities (that is, verbal, non-verbal and quantitative reasoning abilities) as predictors of chemistry achievement among secondary school students. Therefore, this study sought to investigate cognitive abilities (that is, verbal, non-verbal and quantitative reasoning abilities) as predictors of chemistry achievement among secondary school students in Delta Central Senatorial Destrict.

CHAPTER THREE

RESEARCH METHOD AND PROCEDURE

This chapter deals with research procedures and techniques that were used for the study. They are discussed under the following headings.

- Design of the Study
- Population of the Study
- Sample and Sampling Technique
- Research Instrument
- Validity of Research Instrument
- Reliability of Research Instrument
- Treatment Procedure
- Method of Data Analysis

Design of the Study

This study employed the one group pretest-posttest pre-experimental design. There was no randomization but the use of intact classes and there was no control group. The design matrix is represented below;

Table 1: Representation of One-group Pretest-Posttest Pre-experimental Design.

Pretest	Treatment	Posttest
O_1	X	O_2

O_1 = Pretest; O_2 = Posttest

X stands for treatment condition which is Lecture method.

Population of the Study

The population of this study consisted of 8,819 male and 8140 female students from 178 public senior secondary schools (SS 1) in Delta Central senatorial District. Below is the table showing the eight (8) Local Government Areas and the number of Senior Secondary School (SS1) students in the Senatorial District.

Table 2: Population of the study (SS1 Students in Delta Central Senatorial District)

Local Government Areas	Number of Public Senior Secondary schools	Number of male students (SS1)	Number of female students (SS1)	Total
Ethiope East	26	862	837	**1699**
Ethiope West	22	897	841	**1738**
Ughelli South	24	987	977	**1988**
Ughelli North	42	2222	1749	**3971**
Udu	14	874	1011	**1885**
Uvwie	16	1332	1301	**2633**
Okpe	16	521	536	**1057**
Sapele	18	1124	888	**2012**
Total	**178**	**8819**	**8140**	**17137**

Sources: Update of statistical data for public senior secondary schools, 2012/2013 session by Ministry of Education (Basic and Secondary), Asaba.

Sample and Sampling Techniques

Three (3) Local Government Areas out of the eight (8) Local Government Areas in Delta Central Senatorial District were used for the study. The researcher sampled six (6) public secondary schools, two (2) schools from each of the three (3) Local Government Areas. The three (3) Local Government areas and the six (6) research schools were obtained by sampling with replacement. The names of all the Local Governments were written on a slip of paper. The slip of paper were folded and put in a container. After a thorough reshuffling, the researcher, not looking into the container, dipped his hand and picked one slip. He unfolded the slip, recorded the name of the Local Government written on the slip, folded it again and put it back into the container. This process was repeated until the researcher drew the three Local Government Areas from the Senatorial District. The same process was used to obtain all the six schools from the three Local Government Areas. The sample size of 309 Senior Secondary (SS1) chemistry students from the six (6) sampled schools was used for the study. The two sexes were represented in the sample. Sampling techniques involved the use of non-randomized intact classes in the six sampled schools. That is, the researcher went to the science arm of SSI in each of the sampled schools and studied the students in the classes.

The names of the Local Government areas, names of the schools and number of SS 1 students are tabulated as follow;

Table 3: The six (6) sampled Local Government Areas, Schools and the number of SS1 students in the classes.

NAME OF LOCAL GOVERNMENT AREA	NAME OF SCHOOL	NUMBER OF SS 1 STUDENTS		
		M	**F**	**TOTAL**
Ethiope East	Abraka Grammar School, Abraka	22	27	**49**
	Umiaghwa Secondary School, Oria	25	26	**51**
Ughelli North	Uwheru Grammar School, Uwheru	19	28	**47**
	Orogun Grammar School, Orogun	23	31	**54**
Sapele	Orodje Secondary School, Sapele	21	29	**50**
	Urhiapele Sen. Sec. School, Sapele	27	31	**58**
Total		**137**	**172**	**309**

Research Instrument

Two instruments were used for this study. They include-

1. Cognitive ability test (CogAT).
2. Chemistry achievement test (CAT)

Cognitive ability test (CogAT) is an aptitude test that measures a student's general and specific cognitive abilities. This test measures learned reasoning and problem-solving skills in three areas: verbal reasoning, quantitative reasoning, and nonverbal reasoning. Verbal reasoning Score reveals the student's ability to perceive the meaning of and relationships between words and word combinations. Students are tested in this area by performing sentence completion, solving verbal analogies, and figuring out the relationships between the meanings of words. Quantitative reasoning score reveals the student's ability to comprehend and employ numbers that permit him to understand relationships, computational rules, and problem-solving techniques. This ability is tested through asking the student to build and solve equations, recognize number series, and demonstrate an understanding of the relationship between numbers and their values. Nonverbal reasoning score indicates the student's ability to spatially manipulate and reason with geometric patterns and figures. Students who score well in this area learn best through visuals--pictures, objects, models-simulations, and hands-on activities. Nonverbal abilities are determined from a student's ability to solve figure analogies, classify designs, and exercise skill in recognizing figures in dimension. The CogAt contains sixty (60) objectives divided into three sections; test of verbal, non-verbal and quantitative reasoning abilities. This is shown in appendix A.

Chemistry achievement test (CAT) is a test to measure students' academic achievement in chemistry. The test was constructed to cover the content areas that the students were taught in chemistry. The content areas included introduction to chemistry, nature of matter and separation techniques, physical and chemical change, element, compounds and mixture, atomic structure, relative atomic mass and relative molecular mass. The CAT contained multiple choice questions. The CAT is shown in appendix B. Lecture method was used to teach the sampled students. The lecture method lesson note is shown in appendix C.

Validity of Research Instrument

The cognitive ability test which measures students' verbal, non-verbal and quantitative reasoning abilities was created by the researcher. The items of the cognitive ability test were drawn from standardized cognitive/placement examination questions by Delta State Ministry of Education (Basic & Secondary). This cognitive ability test is content free and it is of general application irrespective of the of the students' level in the school (Gregory, 2011). The face and content validities of the cognitive ability test were determined by three experts in the Department of curriculum and integrated science, and Guidance and Counseling from Delta State University Abraka. The experts were requested to determine if the face and content validities of the instrument were appropriate. Based on their constructive criticism and useful suggestions, necessary corrections of the instrument were made. The content validity for the CogAT ensured as shown in table 4.

Table 4: Table of Specification for the Cognitive Ability Test.

Content Level	Verbal Reasoning			Non-verbal Reasoning			Quantitative Reasoning			Total
	Sentence completion	**Verbal analogies**	**Verbal classification**	**Figure classification**	**Image analysis**	**Figure analogies**	**Number series**	Quantitative relation	Equation building	
Knowledge	2	2	2	2	2	2	2	2	2	**18**
Comprehension	1	1	1	2	1	1	1	1	1	**10**
Application	1	1	1	1	1	1	1	1	1	**9**
Analysis	1	2	2	1	1	1	1	2	2	**13**
Synthesis	1	1	1	1	2	1	-	1	2	**10**
Total	**6**	**7**	**7**	**7**	**7**	**6**	**5**	**7**	**8**	**60**
Percentage	**10%**	**11.7%**	**11.7%**	**11.7%**	**11.7%**	**10%**	**8.3%**	**11.7%**	**13.2%**	**100%**

Also, the chemistry achievement test was developed by the researcher using standardized chemistry questions from past promotion examinations conducted by Delta State Ministry of Education for senior secondary school (SS 1) students. The chemistry achievement test was given to three experts in the Department of curriculum and integrated science, and guidance and counseling from Delta State University Abraka to read through in order to ensure its face and content validities. Necessary corrections were made to ensure that the instrument is able to measure what it was designed to measure effectively. A table of specification was also given to enable the experts determine the content validity of the chemistry achievement test. The table of specification is shown as table 5.

Table 5: Table of Specification for the Chemistry Achievement Test

CONTENT AREAS	PROCESSES						TOTAL
	KNOWLEDGE	COMPREHENSION	APPLICATION	SYNTHESIS	ANALYSIS	EVALUATION	
Introduction to chemistry	1	3	1	1	2	-	**8**
Nature of Matter and Separation Techniques	2	1	2	2	2	-	**9**
Physical and Chemical Changes	2	1	1	2	2	-	**8**
Element, Compound and Mixture	2	2	1	2	1	-	**8**
Atomic Structure	3	2	2	1	1	-	**9**
Relative Atomic Mass and Relative Molecular Mass	2	2	2	1	1	-	**8**
TOTAL	**12**	**11**	**9**	**9**	**9**	**-**	**50**
PERCENTAGE	**24%**	**22%**	**18%**	**18%**	**18%**	**-**	**100%**

Reliability of Research Instrument

Reliability refers to the consistency and dependability of the data collected. In other words, reliability of an instrument is the extent to which that instrument is consistent in measuring what it intends to measure. In this study, the instrument, cognitive ability test was administered to 15 students that were not part of the sample of the study but from the same population. The reason for this was to avoid contamination. The reliability of the whole instruments was obtained to be 0.80 by applying Kuder Richardson 21. This high value suggests that the cognitive ability test is reliable for a study of this nature. This is shown in appendix D.

Also, the same process was repeated with the chemistry achievement test and its reliability value was obtained to be 0.70 by applying Kuder Richardson 21 showing that the chemistry achievement test is reliable for a study of this kind. This is shown in appendix E

Treatment Procedure

The researcher trained six (6) chemistry teachers or research assistants for two days. The six chemistry teachers that were used for this study were trained together on the skills of using Lecture method of teaching (Appendix F) and the skills of administering the cognitive ability test (Appendix A), pretest and posttest (Appendix B). The first day was spent discussing the characteristics and procedures of using lecture method. On the second day, the teachers were trained using the lesson notes developed by the researcher. The lesson notes specifically defined the steps involved in using lecture method and the specific roles teachers should play in each step. This was done to ensure that all the instructional presentations follow the same formats for all the intact-classes. The second day was also spent on practice where the teachers were requested to demonstrate what they have been trained on. The training came to a close when the researcher was convinced that the chemistry teachers trained could accurately apply the lecture method in teaching the selected content areas. The six (6) chemistry instructors were exposed to the chemistry content areas that were taught. These included introduction to chemistry, nature of matter and separation techniques, physical and chemical change, element, compounds and mixture, atomic structure, relative atomic mass and relative molecular mass. The lecture method lesson note is shown in appendix F.

The six (6) chemistry teachers had similar experiences on teaching skills based on their training as teachers and they were all graduates of science education (chemistry). The chemistry teachers were assigned to the six (6) intact classes. All the classes were taught by their respective teachers (research assistants) for the space of six weeks.

A week before the commencement of treatment, the researcher and the six chemistry teachers administered the cognitive ability test to all the intact-classes in the sampled schools. The purpose of this cognitive ability test was to measure the students' reasoning abilities in order to categorize them into high and low verbal, non-verbal and quantitative reasoning abilities. Students that achieved average in these three abilities were not included in the analysis of results due to their tendency of becoming high or low cognitive abilities. The cognitive ability test is shown in Appendix A

Two days before the instruction began, all the six groups were pre-tested with the 50 items on the chemistry achievement test. This was done to determine the equivalence of the groups before treatment and to be sure that any noticed change later was due to students varying cognitive abilities. On treatment and in each of the specific classrooms the teacher taught the students with the lecture method on which they have been trained.

At the end of six weeks of instruction, all the six intact-classes were post-tested with the 50 items on the chemistry achievement test. The posttest questions contain the same questions as the pretest, except that, the posttest questions were re-arranged in numbering so as not to make it obvious to any pretested student that he/she was writing the same test for the second time.

Students' response to the cognitive ability test, the pretest and the post-test were collected, marked and scored by the researcher and research assistants.

Method of Data Analysis

Data analysis involved the use of mean, standard deviation and t-test. All the research questions were answered by the use of mean and standard deviation. Student's t-test was used to test hypotheses 1 – 6 while hypothesis 7 was tested with Pearson Product Moment Correlation statistics.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION

In this chapter, the data collected were analyzed based on the seven research questions and hypotheses that were raised. The results obtained are hereby presented as follow-

Answering of Research Questions

Research Question 1: Is there any difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities?

Table 6: Chemistry achievement mean scores and standard deviations of students with high verbal reasoning abilities and those with low verbal reasoning abilities. (See Appendix F)

Cognitive Abilities	N	Mean	Standard Deviation
High Verbal Reasoning Students	20	37.0	7.0
Low Verbal Reasoning Students	20	22.0	6.0

Table 6 showed that students with high verbal reasoning abilities had a mean score of 37.0 in chemistry achievement test while those with low verbal reasoning abilities had 22.0. The difference in mean achievement score between students with high verbal reasoning abilities and those with low verbal reasoning abilities is 15.0. Also, the standard deviations of both high verbal reasoning students and low verbal reasoning students are 7.0 and 6.0 respectively, with a difference of 1.0.

Therefore, there is a difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities.

Research Question 2: Is there any difference in chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities?

Table 7: Chemistry achievement mean scores and standard deviations of students with high quantitative reasoning abilities and those with low quantitative reasoning abilities. (See Appendix G)

Cognitive Abilities	N	Mean	Standard Deviation
High Quantitative Reasoning Students	20	40.0	6.0
Low Quantitative Reasoning Students	20	24.0	8.0

Table 7 showed that students with high quantitative reasoning abilities had a mean score of 40.0 in chemistry achievement test while those with low quantitative reasoning abilities had 24.0. The difference in mean achievement score between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities is 16.0. Also, the standard deviations of both high quantitative reasoning students and low quantitative reasoning students are 6.0 and 8.0 respectively, with a difference of 2.0. This shows that, there is a difference in chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities.

Research Question 3: Is there any difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities?

Table 8: Chemistry achievement mean scores and standard deviations of students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities. (See Appendix H)

Cognitive Abilities	N	Mean	Standard Deviation
High Non-verbal Reasoning Students	20	39.0	7.0
Low Non-verbal Reasoning Students	20	27.0	6.0

Table 8 showed that students with high non-verbal reasoning abilities had a mean score of 39.0 in chemistry achievement test while those with low non-verbal reasoning abilities had 27.0. The difference in mean achievement score between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities is 12.0. Also, the standard deviations of both high non-verbal reasoning students and low non-verbal reasoning students are 7.0 and 6.0 respectively, with a difference of 1.0. This shows that, there is a difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities.

Research Question 4: Is there any difference in chemistry achievement between male and female students with high verbal reasoning abilities?

Table 9: Chemistry achievement mean scores and standard deviations of male and female students with high verbal reasoning abilities.
(See Appendix I)

Male and Female Students' Cognitive Abilities	N	Mean	Standard Deviation
Male Students with High Verbal Reasoning Abilities	10	38.0	4.0
Female Students with High Verbal Reasoning Abilities	10	38.0	4.0

Table 9 showed that both male and female students with high verbal reasoning abilities had the same mean scores of 38.0 in chemistry achievement test, showing no difference in their achievement. Also, the standard deviation of both male and female students with high verbal reasoning abilities in chemistry achievement test was the same as 4.0. This simply shows that, there is no difference in chemistry achievement between male and female students with high verbal reasoning abilities.

Research Question 5: Is there any difference in chemistry achievement between male and female students with high non-verbal reasoning abilities?

Table 10: Chemistry achievement mean scores and standard deviations of male and female students with high non-verbal reasoning abilities. (See Appendix J)

Male and Female Students' Cognitive Abilities	N	Mean	Standard Deviation
Male Students with High Non-verbal Reasoning Abilities	10	33.0	6.0
Female Students with High Non-verbal Reasoning Abilities	10	33.0	4.0

Table 10 showed that male and female students with high non-verbal reasoning abilities had the same mean scores of 33.0 in chemistry achievement test, showing no difference in their achievement. Also, there is a difference of 2.0 in standard deviation of chemistry achievement test between male and female students with high non-verbal reasoning abilities but since their mean scores in chemistry achievement test is the same, the overall results show that, there is no difference in chemistry achievement between male and female students with high non-verbal reasoning abilities.

Research Question 6: Is there any difference in chemistry achievement between male and female students with high quantitative reasoning abilities?

Table 11: Chemistry achievement mean scores and standard deviations of male and female students with high quantitative reasoning abilities. (See Appendix K)

Male and Female Students' Cognitive Abilities	**N**	**Mean**	**Standard Deviation**
Male Students with High Quantitative Reasoning Abilities	10	42.0	4.0
Female Students with High Quantitative Reasoning Abilities	10	42.0	4.0

Table 11 showed that male and female students with high quantitative reasoning abilities had the same mean scores of 42.0 in chemistry achievement test, showing no difference in their achievement. Also, the standard deviation of both male and female students with high verbal reasoning abilities in chemistry achievement test was the same as 4.0. These results show that, there is no difference in chemistry achievement between male and female students with high quantitative reasoning abilities.

Research Question 7: Is there any relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry?

Table 12: Relationship between students' cognitive abilities and their achievement in chemistry. (See Appendix L)

Cognitive Ability/Chemistry Achievemt	**N**	**Correlation Coefficient (r)**
Cognitive Ability in the three Classes of Reasoning Abilities	15	0.70
Achievement in Chemistry	15	

Table 12 showed the relationship between students' cognitive ability in the three classes of reasoning abilities (that is verbal, non-verbal and quantitative reasoning abilities) and their achievement in chemistry. Table 12 showed that there is a correlation coefficient of 0.70 between students' cognitive ability in the three classes of reasoning abilities and their chemistry achievement. This high correlation coefficient value shows there is a relationship. Therefore, there is a relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry.

Testing of Research Hypotheses

Hypothesis One (Ho_1): There is no significant difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities.

Table 13: t-test summary comparing chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities. (See Appendix F)

Categories of Cognitive Abilities	N	□	SD	df	t-Cal.	t-Crit.	Level of Significance	Remark
High Verbal Reasoning Students	20	37.0	7.0	38	7.28	2.01	0.05	Significant
Low Verbal Reasoning Students	20	22.0	6.0					

Table 13 showed that t-calculated (7.28) is greater than t-critical (2.01) meaning there is significant difference in chemistry achievement between students with high verbal reasoning and those with low verbal reasoning abilities. Therefore, hypothesis one which states that there is no significant difference in chemistry achievement between students with high verbal reasoning and those with low verbal reasoning abilities is rejected.

Hypothesis Two (Ho_2): There is no significant difference in chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities.

Table 14: t-test summary comparing chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities. (See Appendix G)

Categories of Cognitive Abilities	N	□	SD	df	t-Cal.	t-Crit.	Level of Significance	Remark
High Quantitative Reasoning Students	20	40.0	6.0	38	7.14	2.01	0.05	Significant
Low Quantitative Reasoning Students	20	24.0	8.0					

Table 14 showed that t-calculated (7.14) is greater than t-critical (2.01) meaning there is significant difference in chemistry achievement between students with high quantitative reasoning and those with low quantitative reasoning abilities. Therefore, hypothesis two which states that there is no significant difference in chemistry achievement between students with high quantitative reasoning and those with low quantitative reasoning abilities is rejected.

Hypothesis Three (Ho_3): There is no significant difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities.

Table 15: t-test summary comparing chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities. (See Appendix H)

Categories of Cognitive Abilities	N	☐	SD	df	t-Cal.	t-Crit.	Level of Significance	Remark
High Non-verbal Reasoning Students	**20**	**39.0**	**7.0**	**38**	**5.83**	**2.01**	**0.05**	Significant
Low Non-verbal Reasoning Students	**20**	**27.0**	**6.0**					

Table 15 showed that t-calculated (5.83) is greater than t-critical (2.01) meaning there is significant difference in chemistry achievement between students with high non-verbal reasoning and those with low non-verbal reasoning abilities. Therefore, hypothesis three which states that there is no significant difference in chemistry achievement between students with high non-verbal reasoning and those with low non-verbal reasoning abilities is rejected.

Hypothesis Four (Ho_4): There is no significant difference in chemistry achievement between male and female students with high verbal reasoning abilities.

Table 16: t-test summary comparing chemistry achievement between male and female students with high verbal reasoning abilities. (See Appendix I)

Categories of Cognitive Abilities	N	□	SD	df	t-Cal.	t-Crit.	Level of Significance	Remark
Male Students with High Verbal Reasoning Abilities.	10	38.2	4.3	18	0.11	2.10	0.05	Not Significant
Female Students with High Verbal Reasoning Abilities	10	38.4	4.2					

Table 16 showed that t-critical (2.10) is greater than t-calculated (0.11) meaning there is no significant difference in chemistry achievement between male students with high verbal reasoning and female students with high verbal reasoning abilities. Therefore, hypothesis four which states that there is no significant difference in chemistry achievement between male students with high verbal reasoning and female students with high verbal reasoning abilities is upheld.

Hypothesis Five (Ho_5): There is no significant difference in chemistry achievement between male and female students with high non-verbal reasoning abilities.

Table 17: t-test summary comparing chemistry achievement between male and female students with high non-verbal reasoning abilities. (See Appendix J)

Categories of Cognitive Abilities	N	☐	SD	df	t-Cal.	t-Crit.	Level of Significance	Remark
Male Students with High Non-verbal Reasoning Abilities.	10	33.0	5.5	18	0.19	2.10	0.05	Not Significant
Female Students with High Non-verbal Reasoning Abilities	10	33.4	3.5					

Table 17 showed that t-critical (2.10) is greater than t-calculated (0.19) meaning there is no significant difference in chemistry achievement between male students with high non-verbal reasoning and female students with high non-verbal reasoning abilities. Therefore, hypothesis five which states that there is no significant difference in chemistry achievement between male students with high non-verbal reasoning and female students with high non-verbal reasoning abilities is upheld.

Hypothesis Six (Ho_6): There is no significant difference in chemistry achievement between male and female students with high quantitative reasoning abilities.

Table 18: t-test summary comparing chemistry achievement between male and female students with high quantitative reasoning abilities. (See Appendix K)

Categories of Cognitive Abilities	N	☐	SD	df	t-Cal.	t-Crit.	Level of Significance	Remark
Male Students with High Quantitative Reasoning Abilities.	10	41.7	4.3	18	0.05	2.10	0.05	Not Significant
Female Students with High Quantitative Reasoning Abilities	10	42.1	4.2					

Table 18 showed that t-critical (2.10) is greater than t-calculated (0.05) meaning there is no significant difference in chemistry achievement between male students with high quantitative reasoning and female students with high quantitative reasoning abilities. Therefore, hypothesis six which states that there is no significant difference in chemistry achievement between male students with high quantitative reasoning and female students with high quantitative reasoning abilities is upheld.

Hypothesis Seven (Ho_7): There is no significant relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry.

Table 19: Relationship between students' cognitive abilities and their achievement in chemistry. (See Appendix L)

Cognitive Abilities	N	Correlation Coefficient (r)	Coefficient of Determination (r^2)	Interpretation of r
Cognitive Abilities	15	0.70	0.49	High positive correlation
Achievement in Chemistry	15			

Table 19 showed that the coefficient of determination was obtained to be 0.49 which means that 49% of chemistry achievement is accounted for or predicted by cognitive abilities. Therefore, hypothesis seven which states that there is no significant relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry is rejected.

Discussion of Results

This study was carried out to investigate cognitive abilities as predictors of chemistry achievement among secondary school students in Delta Central Senatorial District. The study also examined the effect of sex differences in cognitive abilities on students' achievement in chemistry.

Research question 1 examined the difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities. Analysis of results showed that students with high verbal reasoning abilities had a mean score of 37.0 in chemistry achievement test while those with low verbal reasoning abilities had 22.0. The difference in mean achievement score between students with high verbal reasoning abilities and those with low verbal reasoning abilities is 15.0. Also, the standard deviations of both high verbal reasoning students and low verbal reasoning students were 7.0 and 6.0 respectively, with a difference of 1.0. This established that there is a difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities. Therefore, there is a difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities. This result was subjected to inferential statistics to find out whether this difference is statistically significant. The t-test statistics was employed to test hypothesis 1 (Ho_1). The result of the test showed a statistical significant difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities. The t-test statistics showed that t-calculated (7.28) is greater than t-critical (2.01). Thus, hypothesis one (Ho_1) is rejected. This finding is in line with those of Colom, Escorial, Shih and Pivado (2007) who found out that a crucial factor in predicting academic achievement remains an individual's level of reasoning ability.

The answer to research question 2 showed that there is a difference in chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities. This result was subjected to inferential statistics to find out whether this difference is statistically significant. The t-test statistics was employed to test hypothesis two (Ho_2). The result of the test showed a statistical significant difference in chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities. The t-test statistics showed that t-calculated (7.14) is greater than t-critical (2.01). Thus, hypothesis two (Ho_2) was rejected. This finding agrees with those of Ackerman and Heggestad (1997) who also discovered in their study that a number of cognitive abilities such as quantitative reasoning abilities help to shape an individual's academic performance.

Similarly, research Question 3 which examined the difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities showed that the difference in the mean achievement score between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities is 12.0. This shows that, there is a difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities. The t-test statistics of this result revealed that the t-calculated (5.83) is greater than t-critical (2.01). Thus, the hypothesis three (Ho_3) was rejected. Meaning that, there is a statistical significance difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities. This finding agrees with the findings of O'Connor and Paunonen (2007) who also found out of cognitive abilities help to enhance an individual's academic performance.

Research question 4 examined the non-significant difference in chemistry achievement between male and female students with high verbal reasoning abilities. The analysis of results showed that male and female students with high verbal reasoning abilities had the same mean scores of 38.0 in chemistry achievement test, showing no difference in their achievement. Also, the standard deviation of both male and female students with high verbal reasoning abilities in chemistry achievement test was the same as 4.0. This simply shows that, there is no difference in chemistry achievement between male and female students with high verbal reasoning abilities. This result was subjected to inferential statistics. The t-test statistics was employed to test hypothesis four (Ho_4). The t-test statistics showed that t -critical (2.10) is greater than t-calculated (0.11). Thus, the hypothesis four (Ho_4) was upheld. Meaning that, there is no a statistical significance difference in chemistry achievement between male and female students with high verbal reasoning abilities. This finding is in line with that of Benbow and Stanley (1996) who discovered earlier that male and female students with the same reasoning abilities were found to be essentially equivalent in academic achievement.

The answer to research question 5 showed that there is no difference in chemistry achievement between male and female students with high non-verbal reasoning abilities. The analysis of results showed that male and female students with high non-verbal reasoning abilities had the same mean scores of 33.0 in chemistry achievement test, showing no difference in their achievement. This non significant difference was subjected to t-test statistics and the result of the t-test statistics showed that t-critical (2.10) is greater than t-calculated (0.19). Thus, hypothesis five (Ho_5) was upheld. Meaning, there is no significant difference in chemistry achievement between male and female students with high non-verbal reasoning abilities. This finding is also in line with that of Benbow and Stanley (1996) who discovered earlier that male and female students with the same reasoning abilities were found to be essentially equivalent in academic achievement.

In the same way research question 6 which examined the non-significant difference in chemistry achievement between male and female students with high quantitative reasoning abilities revealed that male and female students with high quantitative reasoning abilities had the same mean scores of 42.0 in chemistry achievement test. This shows that there is no difference in chemistry achievement between male and female students with high quantitative reasoning abilities. This non-significant difference was subjected to inferential statistics of students' t-test. The t-test statistics showed that t-critical (2.10) is greater than t-calculated (0.05). Thus, the hypothesis six (Ho_6) was upheld. Meaning, there is no significant difference in chemistry achievement between male and female students with high quantitative reasoning abilities. This finding also agrees with that of Benbow and Stanley (1996) who discovered earlier that male and female students with the same reasoning abilities were found to be essentially equivalent in academic achievement.

Finally, research question 7 and null hypothesis seven examined the relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry. Using correlation statistics, the results showed that there is a correlation coefficient of 0.7 between students' cognitive ability in the three classes of reasoning abilities and their chemistry achievement. This high correlation coefficient value shows there is a relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry. Thus, hypothesis seven (Ho_7) was rejected. Meaning, there is statistically significant relationship between students' cognitive ability in the three classes of reasoning abilities and their achievement in chemistry. This finding is in line with those of Binet & Simon (1916) cited in Scot & Matthew (2012); Deary (2007); Mackintosh (2008); Lynn and Meisenberg (2010) who found that the average cognitive abilities is highly correlated with the academic achievement of students.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTION FOR FURTHER RESEARCH

This chapter is organized under the following sub-headings-

- Summary of the Research
- Major Findings
- Conclusions
- Contribution of the Research to Knowledge
- Recommendations
- Suggestions for Further Studies

Summary of the Research

This study was concerned with investigating cognitive abilities as predictors of chemistry achievement among secondary school students in Delta Central Senatorial District. The research instruments used were Cognitive Ability Test and Chemistry Achievement Test with an intervening package of lecture method lesson plan. The design of the study was one group pretest-posttest pre-experimental design. The population of the study was 8,819 male and 8,140 female students and a sample size of 137 male and 172 female students from public secondary schools

(SS 1) in Delta State Senatorial District. Data collected were analyzed using mean, standard deviation, t-test and Pearson Product Moment Correlation Statistics.

Seven research questions were raised. They are-

1. Is there any difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities?
2. Is there any difference in chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities?
3. Is there any difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities?
4. Is there any difference in chemistry achievement between male and female students with high verbal reasoning abilities?
5. Is there any difference in chemistry achievement between male and female students with high non-verbal reasoning abilities?
6. Is there any difference in chemistry achievement between male and female students with high quantitative reasoning abilities?
7. Is there any relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry?

Also, seven null hypotheses were formulated to be tested at 0.05 level of significance. They are –

$Ho_{1.}$ There is no significant difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities.

$Ho_{2.}$ There is no significant difference in chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities.

$Ho_{3.}$ There is no significant difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities.

$Ho_{4.}$ There is no significant difference in chemistry achievement between male and female students with high verbal reasoning abilities.

$Ho_{5.}$ There is no significant difference in chemistry achievement between male and female students with high non-verbal reasoning abilities.

$Ho_{6.}$ There is no significant difference in chemistry achievement between male and female students with high quantitative reasoning abilities.

$Ho_{7.}$ There is no significant relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry.

Hypotheses 1, 2, 3 and 7 were rejected while hypotheses 4, 5 and 6 were upheld. This inferred that there is a significant difference in chemistry achievement between students with high verbal, non-verbal and quantitative reasoning abilities and those with low verbal, non-verbal and quantitative reasoning abilities. The results of the study also showed that there is no difference in chemistry achievement between male and female students with the same level of cognitive abilities. It was also discovered that there is a high positive correlation between students' cognitive abilities (that is verbal, non-verbal and quantitative reasoning abilities) and their achievement in chemistry.

Major Findings

The analysis of result revealed the following findings:

1. There is a difference in chemistry achievement between students with high verbal reasoning abilities and those with low verbal reasoning abilities. This difference between the groups was statistically significant. Thus, null hypothesis one was rejected.

2. There is a difference in chemistry achievement between students with high quantitative reasoning abilities and those with low quantitative reasoning abilities. This difference between the groups was statistically significant.
3. There is a difference in chemistry achievement between students with high non-verbal reasoning abilities and those with low non-verbal reasoning abilities. This difference between the groups was statistically significant.
4. There is no significant difference in chemistry achievement between male and female students with high verbal reasoning abilities.
5. There is no significant difference in chemistry achievement between male and female students with high non-verbal reasoning abilities.
6. There is no significant difference in chemistry achievement between male and female students with high quantitative reasoning abilities.
7. There is a significant relationship between students' cognitive ability score in the three classes of reasoning abilities and their achievement in chemistry.

Conclusions

The main focus of this study was to find out cognitive abilities as predictors of chemistry achievement among secondary school students. The result of the study showed that there is a relationship between cognitive abilities (that is verbal, non-verbal and quantitative reasoning abilities) and achievement in chemistry among secondary school students. This leads to the conclusion that students with higher verbal, non-verbal and quantitative reasoning abilities perform better in chemistry than those with lower verbal, non-verbal and quantitative reasoning abilities. The researcher also concludes that there is no difference in chemistry achievement between male and female students with the same level of verbal, non-verbal and quantitative reasoning abilities.

Contribution of the Research to Knowledge

This study contributes to knowledge in the following ways-

Firstly, this study showed that, when chemistry teachers at the secondary schools teach chemistry considering the varying cognitive abilities of students, it leads to high academic performance among students.

Secondly, the study showed female students are not underachievers in chemistry when their cognitive abilities are well developed. Hence, science achievement is not sex dependent when cognitive ability is controlled.

Recommendation

Since 49% of students achievement in chemistry is accounted for or predicted by their cognitive abilities (that is verbal, non-verbal and quantitative reasoning abilities), the researcher recommends that both teachers and students should engage in activities that would improve cognitive abilities of students. Curriculum planners should ensure that school curriculum is planned and developed with respect to the development of students cognitive abilities since these abilities are necessary for the teaching and learning of chemistry.

Both parents and school teachers should guide and teach students to develop their verbal, non-verbal and quantitative reasoning abilities from the nursery schools. Orientation should be given to students especially those in the rural schools on the benefits of developing cognitive abilities.

Suggestions for Further Studies

Due to limited time, fund and materials available to the researcher, other possible areas that could have been investigated were left out. Hence, the researcher suggests the following areas for further research-

1. This study was restricted to only Delta Central Senatorial District which is one of the three Senatorial Districts in Delta State. It is therefore suggested that similar studies be carried out in the other Senatorial Districts of the State.
2. A similar research can be carried out using other concepts in chemistry or in other science subjects to ascertain the general applicability of the results.
3. Teachers' cognitive abilities as predictors of their teaching effectiveness should be studied by future researchers.

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APPENDIX A

POST GRADUATE SCHOOL,

DEPARTMENT OF CURRICULUM AND INTEGRATED SCIENCE,

DELTA STATE UNIVERSITY, ABRAKA.

CONGNITIVE ABILITY TEST FOR SS I STUDENTS

(*Adopted from Delta State Ministry of Education (Basic & Secondary) past years cognitive/placement examination questions on verbal, non-verbal and quantitative reasoning for primary six pupils & India BIX Online non-verbal Reasoning Test)*

This test is designed to help the researcher measure the cognitive abilities (that is, verbal reasoning, quantitative reasoning and non-verbal reasoning) of senior secondary school I students. Respondents are therefore kindly advised to respond to the test independently and sincerely. All information or answers given will be treated confidentially.

Thank you for your cooperation.

Yours Faithfully,

Egoh A. Josiah

CONGNITIVE ABILITY TEST

INSTRUCTION: ***Time allowed: 1hour***

This cognitive ability test is divided into three SECTIONS; Section A is a test of verbal reasoning, Section B is a test of quantitative reasoning and section C is a test of Non-verbal reasoning.

All Sections contain four options lettered A - D. Students are expected to choose from the options lettered A – D, the one that best answers each of the questions by cycling it as in A

SECTION A: Test of Verbal reasoning

Study this example carefully and answer questions 1 - 3: Shoes are to feet as gloves are to hand.

1. Head is to toe as top is to _____

   A. Middle, B. Bottom C. Last D. Down

2. School is to pupils as army is to ____

   A. Soldiers B. Police C. Students D. Gun

3. Dog is to bark as snake is to ___

   A. Kiss B. Run C. Hiss D. Hide

Example: If the code of SOMETHING is YLBPQAITH then BPQ means MET. Now answer questions 4 – 6

4. If DRAKE in code is PQKJH, then RAKED is ____

   A. QKJHP, B. QJKHP, C. PHKQJ, D. QJKPH

5. If TEAK in code is CGZO, then KATE is ______

   A. OZGC, B. OZCG, C. GCZO, D. CGOZ

6. If FRNTO means CLEAN, then RTOFN means ____

    A. FRNTO, B. OTNRF, C. TORFT, D. LANCE

Questions 7 – 9 contain options A - D. Cycle the option that does not belong to the group among each question

7. A. Butterfly B. Bee C. Arrow D. Mosquito
8. A. Home B. Flat C. School D. Dwelling
9. A. Knee B. Elbow C. Face D. Ankle

Questions 10 – 11 contain options A - D. Cycle the option which is the group name among each question

10. A. Mother B. Sister C. Female D. Girl
11. A. Hot B. Cold C. Warm D. Temperature

From Questions 12 – 13, find the option with the word which is opposite of the word in capitals at the beginning and cycle it.

12. ABSURD: A. Deaf, B. Silly, C. Sensible, D. Clear
13. PERPETUAL: A. Endless, B. Momentary, C. Perfect, D. Timely
14. Harry is taller than David but David is shorter than Ike. Who is the tallest?

    A. Harry, B. David, C. Ike, D. None of the above

15. I want to find a certain number which I will call X. It is Four times as great as another number which is two less than twenty. What is X?

    A. 24 B. 96 C. 48 D. 72

16. Abu was late for school. Ten minutes later he was followed by Nze. Ibrahim arrived five minutes before Nze. Who arrived last?

    A. Abu B. Nze C. Ibrahim D. None of the above.

From questions 17 -20, Find and cycle the option with the word that best complete the following story:

17. A visitor who was staying in a _____ City.

    A. Noisy B. Dirty C. Strange D. Familiar

18. Lost his _____.

A. Mother B. Money C. Wallet D. Way

19. What could he _____?

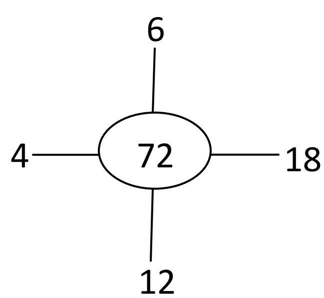
A. Do B. Realize C. Feel D. Write

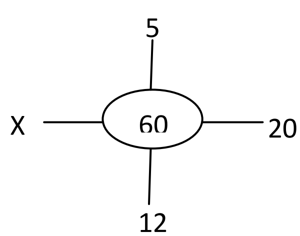
20. Fortunately, he was _____ by a passerby.

A. Promoted B. Rebuked C. Rescued D. Injured

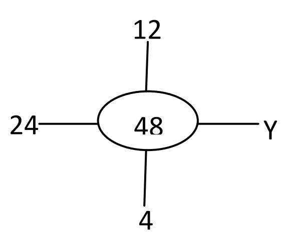
SECTION B: Test of Quantitative reasoning

Study this example carefully and answer questions 1-2



1. 

The value of X is; A. 6, B. 3, C. 6, D. 7

2. 

he value of Y is; A. 5, B. 6, C. 3, D. 2

Study this example carefully and answer questions 3 – 4, $\frac{44 \quad 55 \quad 66 \quad 77 \quad 88}{4 \quad 5 \quad 6 \quad 7 \quad 8}$

3. $\frac{60 \quad 55 \quad 50 \quad 55 \quad 40}{20 \quad Q \quad 30 \quad 35 \quad 40}$ The value of *Q* is; A. 20, B. 45, C. 25, D. 15

4. $\frac{1.1 \quad 1.2 \quad 1.3 \quad 1.4 \quad 1.5}{P \quad 2.4 \quad 2.6 \quad 2.8 \quad 3.0}$ The value of *P* is; A. 2.0, B. 1.5, C. 2.2, D. 1.8

Study this example carefully and answer questions 5 – 7,
$(A\vee B\vee C) = A + B + C$; $(A\vee B\wedge C) = A + B - C$
Therefore, $3\vee 4 = 7$; $5\wedge 2 = 3$

5. What is the value of $(12\wedge 8) \vee 2$? A. 6, B. 10, C. 22, D. 2

6. What is the value of $(16\vee 4) \wedge (10\vee 2)$? A. 1, B. 4, C. 6, D. 8

7. If $48\wedge R = 16$, find R. A. 32, B. 36, C. 40, D. 34

Study this example carefully and answer questions 8 - 9

	P	q	R	S
P	5	8	2	6
Q	0	9	6	3
R	4	0	2	7
S	8	1	7	1

Pp + Qs + Sr = 5 + 3 + 7 = 15
Sr – Rr = 7 – 2 = 5
Rp x Rr = 4 x 2 = 8

8. What is Rs x Pr? A. 240, B. 20, C. 14, D. 24

9. Find the value of Qq – Qr + Rq. A. 3, B. 5, C. 15, D. 20

10. If $x^4 = 16$, then $4^x =$

A. 2, B. 4, C. 8, D. 12, E. 16

11. Arnold has enough gas to last him for thirty days. If he starts using 50% more gas, how many days will the same supply last him?

A. 10, B. 12, C. 15, D. 20

12. 7. If 3x - 6 = 14 - x, then x =? A. 5, B. 3, C. 4, D. 8

13. If a = 2, then 3a + $(a^3)^2$ =? A. 73, B. 70, C. 7, D. 72

14. What is the average of 2, 4, 3, 1, and 10?

A. 5, B. 3, C. 16, D. 4

15. What is the least common multiple of 6, 15 and 21?

A. 27, B. 210, C. 70, D. 1890

16. One fifth of the students in a band play the clarinet. If there are 25 clarinet players, how many students are in the band?

A. 25, B. 15, C. 20, D. 5

Study this example and answer questions 17 – 18

5 Ƶ 3 = 8/2 *6 Ƶ 2 = 8/4* *4 Ƶ 1 = 5/3*

17. 10 Ƶ 5 = y/5. The value of y is- A. 0, B. 1, C. 3, D. 15

18. q Ƶ 3 =18/12. What is the value of q? A. 15, B. 16, C. 21, D. 2

19.

<u>Quantity A</u>	<u>Quantity B</u>
$x^2 + 1$	$2x - 1$

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

20.

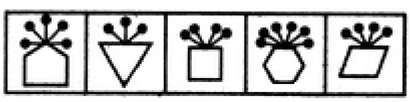
<u>Quantity A</u>	<u>Quantity B</u>
x	*y*

A. Quantity A is greater.
B. Quantity B is greater.
C. The two quantities are equal.
D. The relationship cannot be determined from the information given.

SECTION A: Test of Non-Verbal reasoning

From questions 1 – 7, out of the five figures marked (1), (2), (3), (4) and (5), four are similar in a certain manner. However, one figure is not like the other four. Choose the option lettered A - E with the figure that is different from the rest and cycle it as in A

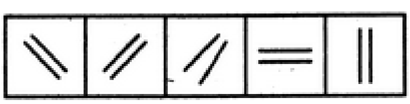
1. Choose the figure which is different from the rest.



(1) (2) (3) (4) (5)

A.1 B.2
C.3 D.4
E.5

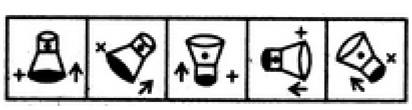
2. Choose the figure which is different from the rest.



(1) (2) (3) (4) (5)

A.1 B.2
C.3 D.4
E.5

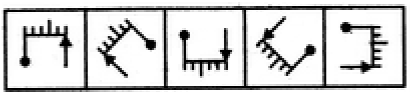
3. Choose the figure which is different from the rest.



(1) (2) (3) (4) (5)

A.1 B.2
C.3 D.4
E.5

4. Choose the figure which is different from the rest.

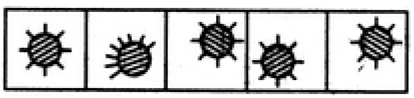


(1) (2) (3) (4) (5)

A.1 B.2
C.3 D.4
E.5

View Answer Workspace Report Discuss in Forum

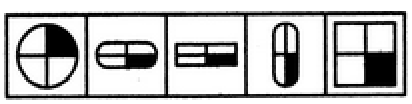
5. Choose the figure which is different from the rest.



(1) (2) (3) (4) (5)

A.1 B.2
C.3 D.4
E.5

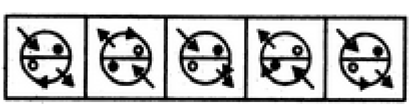
6. Choose the figure which is different from the rest.



(1) (2) (3) (4) (5)

A.1 B.2
C.3 D.4
E.5

7. Choose the figure which is different from the rest.

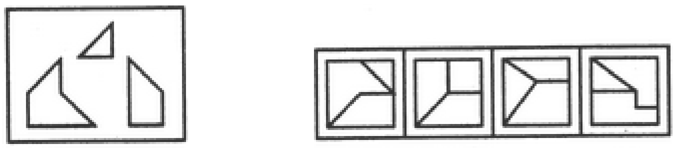


(1) (2) (3) (4) (5)

A.1 B.2
C.3 D.4
E.5

From Questions 8 – 13, find the correct option and circle it as in A

8. Find out which of the figures (1), (2), (3) and (4) can be formed from the pieces given in figure (X).

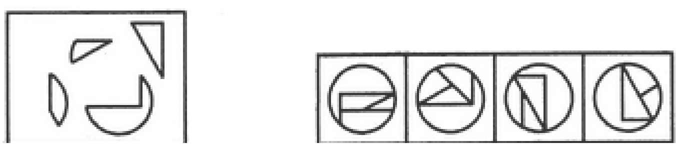


X 1 2 3 4

A. 1 **B.** 2

C. 3 **D.** 4

9. Find out which of the figures (1), (2), (3) and (4) can be formed from the pieces given in figure (X).

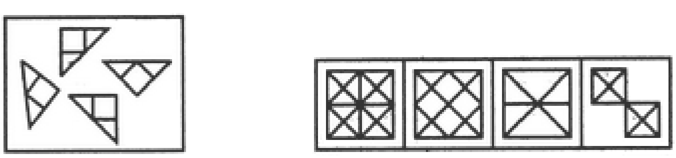


X 1 2 3 4

A. 1 **B.** 2

C. 3 **D.** 4

10. Find out which of the figures (1), (2), (3) and (4) can be formed from the pieces given in figure (X).



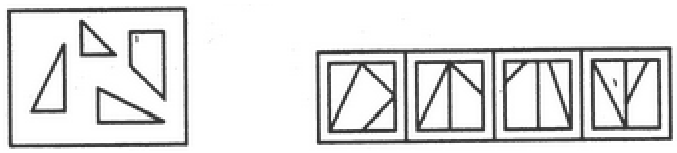
X 1 2 3 4

A. 1 **B.** 2

C. 3 **D.** 4

11. Find out which of the figures (1), (2), (3) and (4) can be formed from the

pieces given in figure (X).

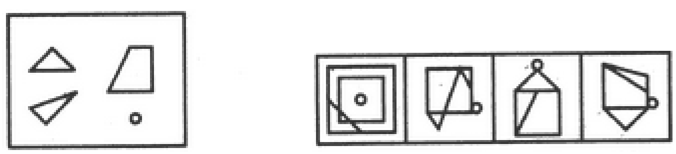


X 1 2 3 4

A. 1 **B.** 2

C. 3 **D.** 4

12. Find out which of the figures (1), (2), (3) and (4) can be formed from the pieces given in figure (X).

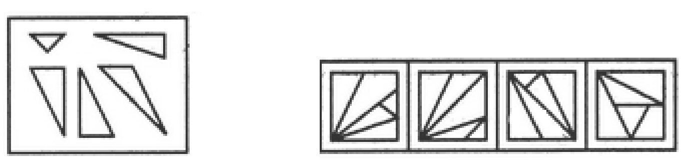


X 1 2 3 4

A. 1 **B.** 2

C. 3 **D.** 4

13. Find out which of the figures (1), (2), (3) and (4) can be formed from the pieces given in figure (X).



X 1 2 3 4

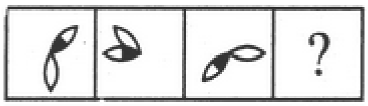
A. 1 **B.** 2

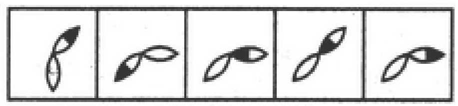
C. 3 **D.** 4

From questions 14 – 20, Each of the following questions consists of two sets of figures. Figures A, B, C and D constitute the Problem Set while figures 1, 2, 3, 4 and 5 constitute the Answer Set. There is a definite relationship between figures A and B. Establish a similar relationship between figures C and D by selecting a suitable figure from the Answer Set that would replace the question mark (?) in fig. (D).

14. Select a suitable figure from the Answer Figures that would replace the question mark (?).

Problem Figures: **Answer Figures:**





(A) (B) (C) (D) **(1) (2) (3) (4) (5)**

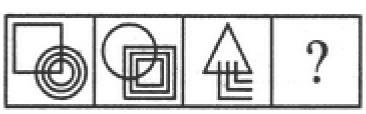
A. 1 **B.** 2

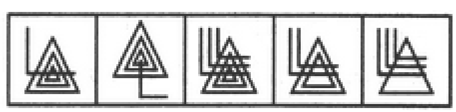
C. 3 **D.** 4

E. 5

15. Select a suitable figure from the Answer Figures that would replace the question mark (?).

Problem Figures: **Answer Figures:**





(A) (B) (C) (D) **(1) (2) (3) (4) (5)**

A. 1 **B.** 2

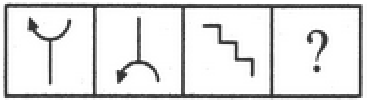
C. 3 **D.** 4

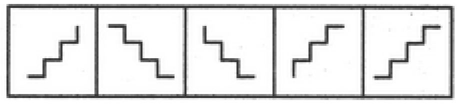
E. 5

16. Select a suitable figure from the Answer Figures that would replace the question

mark (?).

Problem Figures: **Answer Figures:**





(A) (B) (C) (D) (1) (2) (3) (4) (5)

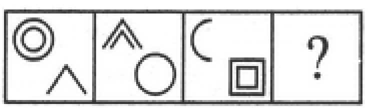
A. 1 **B.** 2

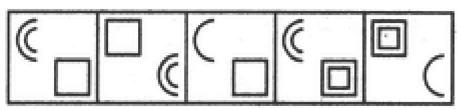
C. 3 **D.** 4

E. 5

17. Select a suitable figure from the Answer Figures that would replace the question mark (?).

Problem Figures: **Answer Figures:**





(A) (B) (C) (D) (1) (2) (3) (4) (5)

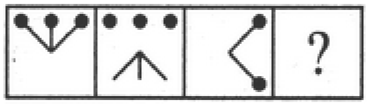
A. 1 **B.** 2

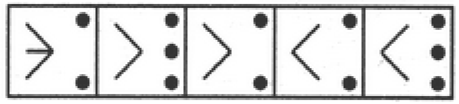
C. 3 **D.** 4

E. 5

18. Select a suitable figure from the Answer Figures that would replace the question mark (?).

Problem Figures: **Answer Figures:**





(A) **(B)** **(C)** **(D)** **(1)** **(2)** **(3)** **(4)** **(5)**

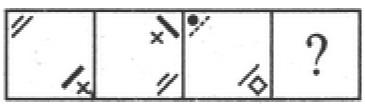
A. 1 **B.** 2

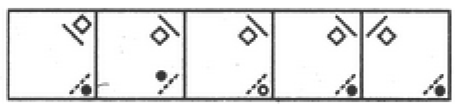
C. 3 **D.** 4

E. 5

19. Select a suitable figure from the Answer Figures that would replace the question mark (?).

Problem Figures: **Answer Figures:**





(A) **(B)** **(C)** **(D)** **(1)** **(2)** **(3)** **(4)** **(5)**

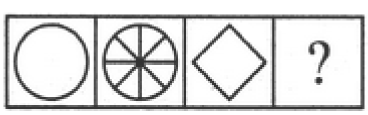
A. 1 **B.** 2

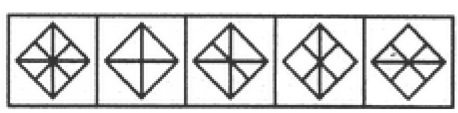
C. 3 **D.** 4

E. 5

20. Select a suitable figure from the Answer Figures that would replace the question mark (?).

Problem Figures: **Answer Figures:**





(A) **(B)** **(C)** **(D)** **(1)** **(2)** **(3)** **(4)** **(5)**

A. 1

B. 2

C. 3

D. 4

E. 5

APPENDIX B

(TACHER-MADE TEST)

POST GRADUATE SCHOOL,

DEPARTMENT OF CURRICULUM AND INTEGRATED SCIENCE,

DELTA STATE UNIVERSITY, ABRAKA.

CHEMISTRY ACHIVEMENT TEST (CAT)

(Adopted from past years promotion examination questions on chemistry conducted by Delta State Ministry of Education for senior secondary school (SS 1) students)

CLASS: SSS 1 TIME 40minutes

INSTRUCTION:

Each of the questions contain four options lettered A – D. Choose the option that best answer each of the question and cycle it as in A

1. Chemistry is defined as __

A. a branch of knowledge which produces chemicals
B. a branch of science which makes physics and biology clearer
C. the older branch science
D. the branch of science which deals with changes of matter

2. Scientific approach to discoveries follows the order which include __

A. further experiment and problem solving
B. theory, negative and positive results and experiments
C. experiments, hypothesis and results
D. observation, hypothesis and experiments

3. Chemical hypothesis is different from chemical law in that

A. hypothesis is not reasonable while law is reasonable
B. hypothesis is a reasonable explanation to observation while law is a statement from a scientist
C. hypothesis is a reasonable explanation to observation while law is a statement which confirms the hypothesis after extensive tests.
D. none of the above

4. Chemical changes around us include all except

A. rusting of iron nails
B. fading of coloured cloth
C. sieving
D. decomposing of green leaves

5. One of these is not a chemical change

A. rusting
B. urine
C. slaking of quicklime
D. fermentation of glucose

6. Separation of mixtures of solids with various sizes include

A. magnetic separation
B. coursing
C. sublimation
D. sieving

7. Separation of different carotenes from carrot root uses a method of

A. chromatography
B. carotinization
C. distillation
D. centrifugation

8. Which of the following statements is incorrect?

A. the addition of water to quicklime is an example of a physical change

B. a chemical change is irreversible and a new substance is formed
C. a physical change can easily be reversed and no new substances are formed
D. separating a mixture by distillation is an example of a physical change.

9. A mixture of oil and water can be easily separated by

A. sublimation
B. evaporation
C. using a separation to dryness
D. fractional crystallization

10. There are basic particles from which matter could be made except

A. salt B. atom C. ion D. molecules

11. Atom is__

A. the smallest part of a substance that can take part in a chemical change
B. the smallest part of a compound that can take part in a chemical change
C. the smallest part of an element that can take part in a chemical change
D. the smallest part of a lattice that can take part in a chemical change

12. Atomicity of Ozone is __

A. 1 B. 2 C. 3 D. 4

13. A molecule is the smallest particle of

A. a matter that can exist in free state
B. an element that can exist in free state
C. a radical that can exist in free state
D. a lattice that can exist in free state

14. ---- is formed when two or more substances are physically joined together.

A. Compound
B. Mixture
C. Glucose
D. Element

15. The relative atomic mass of calcium atom is 40. This means that

A. the mass of calcium is 40g
B. the calcium is 40 times heavier than that of 1 atom of hydrogen
C. calcium is 40 times that of 1g of hydrogen
D. calcium is related to hydrogen through 40 digits

16. The modern standard element with which chemists define relative atomic mass is

A. ^{12}C B. ^{13}C C. ^{3}H D. ^{14}C

17. The relative molecular mass of Lead II trioxonitrate V is (Pb = 108, N = 14, O = 16)

A. 170 B. 222 C. 232 D. 132

18. How many atoms are contained in 1 mole of hydrogen molecule?

A. 18.09×10^{23} atoms
B. 12.06×10^{23} atoms
C. 6.02×10^{23} atoms
D. 6.02×10^{23} molecules

19. A compound that is made up of carbon, hydrogen and oxygen is likely going to

be ---

A. Sand B. Marble C. Glucose D. Urine

20. A molecule of neon is

A. diatomic B. ionic C. monatomic D. triatomic

21. Which of these is the same in isotope of an element?

A. mass number
B. number of neutron
C. number of proton and neutron
C. atomic number

22. The movement of liquid molecules from the surface of the liquid to the gaseous sphere above is known as

A. Brownian movement
B. condensation
C. evaporation
D. liquefaction

23. Ethanoic acid is a compound that contains the following elements.

A. Sodium, Oxygen and Hydrogen
B. Hydrogen, Sulphur and Oxygen
C. Carbon, Hydrogen and Oxygen
D. Silicon and Oxygen

24. The branch of chemistry that deals with the study of matter found in living things, both plants and animals is known as

A. Organic Chemistry
B. Physical Chemistry
C. Inorganic Chemistry
D. Physics

25. The addition of water to calcium oxide leads to

A. a physical change
B. a chemical change
C. the formation of mixture
D. an endothermic change

26. ___ is any atoms or group of atoms which possesses an electric charge

A. ion B. atom C. element D. electrode.

27. The atom is electrically neutral because the number of electrons revolving round the nucleus is equal to the number of _____

A. neutrons in the nucleus
B. protons in the nucleus
C. ions in the nucleus
D. atoms in the nucleus.

28. How many moles of NaOH ar there in 4.0g of the substance? (Na = 23, O = 16, H = 1)

A. 0.4mole B. 0.3mole C. 0.2mole D. 0.1mole.

29. The major reason why chemical reaction occurs among elements is that they have the tendency to

A. attain the nearest noble gas structure

B. become a metal
C. become a non metal
D. become any noble element

30. The major reason why relative atomic masses of elements are not whole numbers is due to the phenomenon called

A. isomerism B. allotropy C. spectroscopy D. isotopy

31. Which of these requires crystallization most?

A. drug making B. cement making C. paint making D.perfume making

32. In paper and gas chromatography respectively, the common feature between them is that they have

A. solid and moving phase

B. stationary phase and moving phase

C. long phase and stationary phase

D. chromatic phase and stationary phase

33. In the discovery of proton, the instrument used is

A. cathode ray tube

B. glass tube and discharge tube

C. discharge tube with terminal cathode

D. discharge tube with central cathode

34. Electron was discovered by

A. John Dalton B. R. Millikan C. J.J. Thomson D. None of the Above

35. The branch of chemistry that deals with the study of matter in our environment which are non-living is known as-

A. Physical Chemistry B. Thermodynamics C. Inorganic chemistry D. Organic Chemistry.

36. The percentage of oxygen in Sulphur IV oxide (S = 32, O = 16) is

A. 5% B. 50% C. 500% D. 25%

37. One of these professions has no need for chemistry.

A. miners B. engineers C. philosophers D. geologists

38. Which is the odd-one out?

A. Air B. Urine C. Brass D. Sand

39. All except one is not a popular criteria for purity

A. melting point B. dielectric constant C. temperature D. centrifugation

40. Fractional distillation is used to separate

A. an insoluble substance from a soluble volatile substance.

B. substances which are adsorbed differently, and which differ in their solubilities in a solvent

C. liquids with differing boiling points

D. gas, liquid or solid impurities from a mixture

41. In an experiment, which of the following observations would suggest that a solid sample is a mixture? The

A. solid can be ground into a fine powder

B. density of the solid is 2.25g dm^{-3}

C. solid begins to melt at 573k but is not completely melted until 648k

D. solid melts at 300k

42. A brand of ink containing cobalt (II), copper (II) and iron (II) ions can best be separated into its various components by

A. fractional crystallization B. fractional distillation

C. sublimation D. chromatograghy

43. A mixture of iron and sulphur can be separated by dissolving the mixture in

A. steam B. dilute hydrochloric acid

C. dilute sodium hydroxide D. benzene

44. Which of the following is a physical change?

A. the bubbling of chlorine into water

B. the bubbling of chlorine into a jar containing hydrogen

C. the dissolution of sodium chloride in water

D. the passing of steam over heated iron

45. An element with atomic number twelve is likely to be

A. electrovalent with a valency of 1 B. electrovalent with a valency of 2

B. covalent with a valency of 2 C. covalent with a valency of 4

46. The atomic numbers of two elements X and Y are 12 and 9 respectively. The

bond in the compound formed between the atoms of these two elements is

A. ionic B. covalent C. neutral D. co-ordinate

47. A metallic ion x^{2+} with an inert gas structure contains 18 electrons. How many protons are there in this ion?

A. 20 B. 18 C. 16 D. 2

48. A change that is usually accompanied with a remarkable amount of heat is known as

A. Physical change C. Chemical change

B. Reversible change D. None of the above

49. What is the amount (in mole) of sodium trioxocarbonate (IV) in 5.3g of the compound? (Na_2CO_3 = 106)

A. 0.05 B. 0.10 C. 0.20 D. 0.50

50. Water has a rather high boiling point despite its low molecular mass because of the presence of

A. Hydrogen bonding B. Covalent bonding

C. Ionic bonding D. Metallic bonding

APPENDIX C

LESSON NOTES FOR SIX WEEKS

WEEK 1

TOPIC: Introduction to Chemistry

CLASS: SSS 1

TIME: 2 Periods of 40 Minutes Each

SEX: Mixed

AGE: 14+

INSTRUCTIONAL MATERIALS: Comprehensive chemistry for senior secondary schools by Jumoke Ezechukwu, charts, chalkboard and chalk.

BEHAVIOURAL OBJECTIVES: By the end of the lesson the students should be able to:

i. Define Chemistry

ii. List 2 career opportunities in chemistry

iii. Give two importance of chemistry

iv. Describe an experimental process

v. Describe adverse effect of chemistry

ENTRY BEHAVIOUR: The students have a thorough understanding of integrated science comprising of chemistry, physics and biology.

PROCEDURE:

STEP 1: Gaining students attention by writing the topic of the lesson on the chalkboard and asking students questions on previous lesson.

STEP 2: Informing students of the objectives to be achieved in the lesson. (See behavioural objective above).

STEP 3: Introducing the lesson by asking students prerequisite learning. What is chemistry?

STEP 4: The teacher develops the topic of the lesson as follow:-

Definition of Chemistry: Chemistry is a branch of science which deals with the study of the nature, composition and properties of matter.

Chemistry can be divided into three parts

1. Inorganic chemistry: This deals with the study of matter in our environment which are non-living
2. Organic chemistry: This deals with the study of matter found in living things which are both plants and animals
3. Physical chemistry: This deals with the study of energy changes accompanying transformation of matter.

Chemistry being an experimental science is studied through experiments. To investigate what causes certain changes around us, chemist must carry out preliminary tests. From the record of observation made, chemists try to make reasonable explanations or hypotheses. Further experiments are made by others to test the hypotheses, they then discuss the results and if they agree in that the results support the hypotheses, within the limit of the available evidences, it becomes a theory. Then a scientific law or principle is stated in support of the theory. This procedure of investigation is known as scientific method.

Importance of Chemistry in everyday Life.

1. Chemistry helps in the production of fuels that are used in everyday life
2. Chemistry helps in the production of drugs
3. Chemistry helps in the production of fertilizers, pesticides and insecticides
4. Synthetic fibres and plastics are manufactured through the knowledge of chemistry

Career Opportunities in Chemistry

1. One can become a chemistry teacher or lecturer
2. One can be trained to become a biochemist
3. Professions such as geology, chemical engineering, medicine, pharmacy, mining engineering etc require the knowledge of chemistry.

Adverse Effect of Chemical Processes

The products of chemical processes from our industries may be harmful to both plants and animals. They make our environment unclean and endangered the life of plants and animals. These products are known as pollutants. Example is oil spillage from refining of petroleum.

STEP 5: Teacher provides a summary of the lesson to enhance students learning process.

STEP 6: Evaluation of the students to determine the extent to which the objectives of the lesson have been achieved. This is done by asking students the following questions.

- What is chemistry?
- List two opportunities in chemisty

STEP 7: Assignment: The teacher gives students the following assignment.

i. Describe the adverse effects of chemistry in our environment

ii. List two importance of chemistry.

WEEK 2

TOPIC: Nature of Matter and Separation Techniques

CLASS: SSS 1

TIME: 2 Periods of 40 Minutes Each

SEX: Mixed

AGE: 14+

INSTRUCTIONAL MATERIALS: Comprehensive chemistry for senior secondary schools by Jumoke Ezechukwu, charts, chalkboard and chalk.

BEHAVIOURAL OBJECTIVES: By the end of the lesson the students should be able to:

1. Define matter
2. Describe states of matter
3. List 5 separation techniques
4. Explain 2 separation techniques

ENTRY BEHAVIOUR: The students have a thorough understanding of introduction to chemistry

PROCEDURE:

STEP 1: Gaining students' attention by writing the topic of the lesson on the chalkboard and asking students questions on previous lesson.

STEP 2: Informing students of the objectives to be achieved in the lesson. (See behavioural objective above).

STEP 3: Introducing the lesson by asking students prerequisite learning. What is matter?

STEP 4: The teacher develops the topic of the lesson as follow:-

Definition of matter: Matter is anything that has mass and occupies space. Example of matter include air, water, plants etc.

States of Matter

Matter can exist in three physical states which are solid state, liquid state and gaseous state. The change of state of matter is usually caused by temperature rise of fall. Example is ice can melt to liquid and liquid can vaporize into a gaseous state.

Separation Techniques

These are techniques that can be used to separate mixture of substances. There are many types of separation techniques which include sieving, filtration, evaporation, distillation, fractional distillation, crystallization, fractional crystallization, sublimation, magnetic separation, decantation, chromatography, precipitation, etc

Sieving: This is used to separate solid particles of different sizes. The sieve separates the smaller particles from the larger ones. Sieving can be used to separate garri particles.

Filration: This is used to separate insoluble solid from a liquid by the use of filter. A mixture of sand and water can be separated with this method

Evaporation: This is a method that can be used to obtain a soluble solid from its solvent. This method can be used to separate a mixture of salt and water

Distillation: Distillation can be used to obtain a solvent from a solution. A mixture of ethanol and water can be separated by distillation.

Fractional distillation: This involves the separation of two or more miscible liquids with close boiling points. Example is the fractional distillation of crude oil.

Sublimation: This is a method that can be used to separate a mixture which contains a substance that can sublime. A mixture of ammonium chloride and sodium chloride can be separated by sublimation method.

Chromatography: Chromatography is a method of separating mixture by taking advantage of their different rates of movement in a solvent over an adsorbent material e.g paper. This method can be used to separate the dyes in a black ink.

Magnetic separation: A magnet is used to separate magnetic substances from non-magnetic particles in a mixture.

Crystallization: This is used to separate salts which decompose easily on heating from their solutions.

Fractional crystallization: This is used to separate two or more solid solutes which are present in the same solution in roughly equal amounts. The solubilities of the different solutes in the given solvent must differ at different temperature.

STEP 5: Teacher provides a summary of the lesson to enhance students learning process.

STEP 6: Evaluation of the students to determine the extent to which the objectives of the lesson have been achieved. This is done by asking students the following questions.

- What is chromatography?
- List three separating techniques you know.

STEP 7: Assignment: The teacher gives students the following assignment.

1. What do you understand by state of matter?
2. What is matter?
3. Explain three separation techniques you have studied.

WEEK 3

TOPIC: Physical and Chemical changes

CLASS: SSS 1

TIME: 2 Periods of 40 Minutes Each

SEX: Mixed

AGE: 14+

INSTRUCTIONAL MATERIALS: Comprehensive chemistry for senior secondary schools by Jumoke Ezechukwu, charts, chalkboard and chalk.

BEHAVIOURAL OBJECTIVES: By the end of the lesson the students should be able to:

1. Define physical and chemical changes
2. Give one example of both physical and chemical changes
3. Differentiate between physical and chemical changes

ENTRY BEHAVIOUR: The students have a thorough understanding of the nature of matter

PROCEDURE:

STEP 1: Gaining students' attention by writing the topic of the lesson on the chalkboard and asking students questions on previous lesson.

STEP 2: Informing students of the objectives to be achieved in the lesson. (See behavioural objective above).

STEP 3: Introducing the lesson by asking students prerequisite learning. What is a physical change?

STEP 4: The teacher develops the topic of the lesson as follow:-

Physical and Chemical Changes

Matter can undergo two types of changes which are physical and chemical changes.

Physical change is a change that is temporal and it can be easily reversed. Dissolving a common salt in water to form a solution is an example of physical change because the salt can be recovered easily by evaporation.

Chemical change is a change that is permanent and it cannot be easily reversed. Dissolving sodium metal in water to form a sodium hydroxide is a chemical change because the change is permanent and cannot be reversed.

Differences between physical and chemical changes

1. Physical change is easily reversed while chemical change is not easily reversible
2. In physical change, no new substance is formed while new substances are formed in chemical change
3. During physical change, very little amount of heat is absorbed or emitted except latent heat of fusion or vaporization while chemical changes are usually accompanied with a remarkable heat change

4. Physical changes do not involve change in mass while chemical changes usually involve change in mass since new substances are formed.

STEP 5: Teacher provides a summary of the lesson to enhance students learning process.

STEP 6: Evaluation of the students to determine the extent to which the objectives of the lesson have been achieved. This is done by asking students the following questions.

- What is physical change?

STEP 7: Assignment: The teacher gives students the following assignment.

Differentiate between chemical and physical changes.

WEEK 4

TOPIC: Element, Compound and Mixture

CLASS: SSS 1

TIME: 2 Periods of 40 Minutes Each

SEX: Mixed

AGE: 14+

INSTRUCTIONAL MATERIALS: Comprehensive chemistry for senior secondary schools by Jumoke Ezechukwu, charts, chalkboard and chalk.

BEHAVIOURAL OBJECTIVES: By the end of the lesson the students should be able to:

1. Define element, compound and mixture.
2. Give one example of each of element, compound and mixture
3. Differentiate between a compound and a mixture

ENTRY BEHAVIOUR: The students have a thorough understanding of physical and chemical changes

PROCEDURE:

STEP 1: Gaining students' attention by writing the topic of the lesson on the chalkboard and asking students questions on previous lesson.

STEP 2: Informing students of the objectives to be achieved in the lesson. (See behavioural objective above).

STEP 3: Introducing the lesson by asking students prerequisite learning. What is an element?

STEP 4: The teacher develops the topic of the lesson as follows:-

Element, Compound and Mixture.

Element: An element is a substance which cannot be split into two or more substances by any chemical means. There are 106 known elements. They can be found in the air, water and under the earth in different percentages. Element may be classified into two groups; Metals and non-metals. Example of metal includes Zinc, Sodium, etc Non-metal includes nitrogen and oxygen. There are some other elements that show the properties of metals and non-metals. They are known as metalloids. Example is silicon and germanium

Compound: A compound is a substance containing two or more different elements which are chemically joined together. Examples of compounds are Glucose which contains carbon, hydrogen and oxygen and Sand which contains silicon and oxygen

Mixture: A mixture is formed when two or more substances are physically joined together. The earth is a mixture of soils, rocks, minerals, living organisms: plants and animals.

Differences between a Mixture and a Compound

The constituents of a mixture can be separated by physical means while the constituents of a compound cannot be separated by physical means

1. The composition of a mixture can vary while that of a compound is fixed
2. Formation of a mixture does not need a great amount of heat while the formation of a compound requires remarkable heat change
3. Properties of a mixture are the sum of those of its individual constituents while the properties of a compound are different from those of its constituents
4. A mixture may be homogeneous or heterogeneous while a compound is homogeneous.
5. A mixture cannot be represented by a chemical formula while a compound can be represented by a chemical formula

STEP 5: Teacher provides a summary of the lesson to enhance students learning process.

STEP 6: Evaluation of the students to determine the extent to which the objectives of the lesson have been achieved. This is done by asking students the following questions.

- What is a compound?

STEP 7: Assignment: The teacher gives students the following assignment.

Differentiate between a mixture and a compound.

WEEK 5

TOPIC: Atomic Structure

CLASS: SSS 1

TIME: 2 Periods of 40 Minutes Each

SEX: Mixed

AGE: 14+

INSTRUCTIONAL MATERIALS: Comprehensive chemistry for senior secondary schools by Jumoke Ezechukwu, charts, chalkboard and chalk.

BEHAVIOURAL OBJECTIVES: By the end of the lesson the students should be able to:

1. Define an atom
2. Describe the atomic structure
3. Define atomic number and mass number.

ENTRY BEHAVIOUR: The students have a thorough understanding of the concepts of element, mixture and compound.

PROCEDURE:

STEP 1: Gaining students' attention by writing the topic of the lesson on the chalkboard and asking students questions on previous lesson.

STEP 2: Informing students of the objectives to be achieved in the lesson. (See behavioural objective above).

STEP 3: Introducing the lesson by asking students prerequisite learning. What is an atom?

STEP 4: The teacher develops the topic of the lesson as follows:-

Definition of atom: An atom is the smallest indivisible particle of an element which ban take part in a chemical reaction.

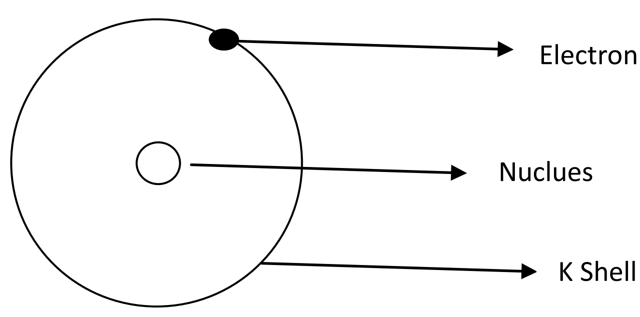
Atomic Structure

Atoms are found to contain three types of particles; protons, neutron and electrons. It consists of centrally placed nucleus which is surrounded byl a cloud of electrons. The nucleus is made up of protons and neutrons.

The proton and neutron each has a mass of one. Proton carries a positive charge while neutron has no charge. The electrons are very light and negatively charged and revolve round the nucleus in an orbital manner in order to neutralize the positive charge in the nucleus.

The atom is electrically neutral because the number of electron revolving round the nucleus is equal to the number of protons in the nucleus.

An Atom



Electronic Distribution: The ways in which electrons are arranged outside and around the nucleus is called electronic configuration. The electrons are arranged in the orbit known as shells. The electrons revolve round the centrally placed nucleus in these shells.

Atomic Number and Atomic Mass

The number of protons in the nucleus of an atom is called atomic number. This atomic number is denoted by a letter Z.

The mass number of an element is denoted by a letter A which is the sum of the protons and neutrons in the element. For example, sodium has a mass number of 23. The number of protons is 11 while neutron is 12.

STEP 5: Teacher provides a summary of the lesson to enhance students learning process.

STEP 6: Evaluation of the students to determine the extent to which the objectives of the lesson have been achieved. This is done by asking students the following questions.

- What is atomic number and mass number?

STEP 7: Assignment: The teacher gives students the following assignment.

- Describe atomic structure.

WEEK 6

TOPIC: Relative Atomic Mass and Relative Molecular Mass

CLASS: SSS 1

TIME: 2 Periods of 40 Minutes Each

SEX: Mixed

AGE: 14+

INSTRUCTIONAL MATERIALS: Comprehensive chemistry for senior secondary schools by Jumoke Ezechukwu, charts, chalkboard and chalk.

BEHAVIOURAL OBJECTIVES: By the end of the lesson the students should be able to:

1. Define relative atomic mass
2. Define relative molecular mass
3. Do simple calculations involving mole, atomic mass number and relative molecular mass number.

ENTRY BEHAVIOUR: The students have a thorough understanding of the concepts of atomic structure.

PROCEDURE:

STEP 1: Gaining students' attention by writing the topic of the lesson on the chalkboard and asking students questions on previous lesson.

STEP 2: Informing students of the objectives to be achieved in the lesson. (See behavioural objective above).

STEP 3: Introducing the lesson by asking students prerequisite learning. What is an atomic mass number?

STEP 4: The teacher develops the topic of the lesson as follows:-

Relative Atomic Mass and Relative Molecular Mass.

The relative atomic mass of an element is defined as the number of times one atom of the element is as heavy as one atom of hydrogen. Aston in 1920 designed an instrument for accurate determination of relative atomic masses of atoms of element. The instrument is called the Mass Spectrometer. The difference in atomic is due to different number of neutrons. These atoms are called isotopes and the phenomenon is called isotopy. Isotopy is the existence of atoms of the element having the same atomic number but different mass numbers.

The relative molecular mass of an element or a compound is defined as the number of times one molecule of the element or compound is as heavy as one-twelfth the mass of one atom of isotopic carbon – 12 having a mass of 12.00 units. The relative molecular mass of an element or a compound is obtain by summing up the values of the relative atomic masses of the atoms of elements present in the molecule as represented by the formula.

Example: Calculate the relative molecular mass of Na_2CO_3 given that Na =23, C = 12, O = 16.

Solution

Na_2CO_3 = 106.0 (Note; Relative molecular mass has no unit)

The Mole

Mole is the SI unit of measurement of mass. It is defined as the amount of substance which contains as many elementary particles as thenumber of atoms contained in 12g of carbon – 12 isotopes. The number of atoms of carbon contained in 12g of carbon – 12 isotopes is 6.02×10^{23}. This is called the Avogadro's constant represented as N. For example, 1 mole of Na represents 1 atom of Na and it contains 6.02×10^{23} atoms of Na.

Example: How many mole atoms of oxygen are there in 0.1mole of carbon (IV) oxide?

Solution

0.1 mole molecule of CO_2 contains 2/1 X 0.1 mole atom of O

= 0.2 mole atoms

Example 2: How many moles of NaOH are there in 4.0g of the substance?

Solution

Molar Mass of NaOH = 40.0g

1.0g is the mass of 1/40 mole NaOH

4.0g is the mass of 1/40 X 4.0mol

= 0.1 mole

Example 3: Calculate the percentage by mass of Oxygen in copper (II) tetraoxosulphate (VI).

Solution

% composition of oxygen = mass of oxygen/molar mass X 100%

64/160 X100 = 40%

STEP 5: Teacher provides a summary of the lesson to enhance students learning process.

STEP 6: Evaluation of the students to determine the extent to which the objectives of the lesson have been achieved. This is done by asking students the following questions.

- What is relative molecular mass?
- What is atomic relative mass?

STEP 7: Assignment: The teacher gives students the following assignment.

- Define the mole
- What is Isotopy?

APPENDIX D

Calculation for the Reliability of Cognitive Ability Test

S/N	Score (X)	X-□	(X-□)^2
1	55	6	36
2	50	1	1
3	40	-9	81
4	52	3	9
5	45	-4	16
6	59	7	49
7	58	9	81
8	49	0	0
9	36	13	169
10	51	2	4
11	57	8	64
12	38	-11	121
13	47	-2	4
14	54	5	25
15	51	2	4
	∑X =739		∑(X-□)^2 =664

$$\square = \frac{\sum X}{N} = 49$$

$$\rho kR21 = \frac{k}{k-1}\ [1 - \frac{\mu(k-\mu)}{k\sigma^2}]$$

Where K = Number of questions

μ = Population mean score

σ^2 = Variance of the total scores of all the people

$\rho kR21$ = Reliability of the test

$$\rho kR21 = 0.8$$

APPENDIX E

Calculation for the Reliability of Chemistry Achievement Test

S/N	Score (X)	X-□	(X-□)^2
1	45	7	49
2	40	2	4
3	30	-8	64
4	42	4	16
5	35	-3	9
6	46	8	64
7	44	6	36
8	39	1	1
9	25	-13	169
10	41	3	9
11	36	-2	4
12	38	0	0
13	37	-1	1
14	31	-7	49
15	43	5	25
	$\sum$X =572		$\sum$(X-□)^2 =500

$$\square = \frac{\sum X}{N} = 37$$

$$\rho kR21 = \frac{k}{k-1}\ [1 - \frac{\mu(k-\mu)}{k\sigma^2}]$$

Where K = Number of questions

μ = Population mean score

σ^2 = Variance of the total scores of all the people

$\rho kR21$ = Reliability of the test

$$\rho kR21 = 0.7$$

APPENDIX F

Calculation of Mean and Standard Deviation for Chemistry Achievement of High Verbal Reasoning Students.

S/N	Chemistry Achievement of High Verbal Reasoning Students (X)	$X-\bar{X}$	$(X-\bar{X})^2$
1	40	3	9
2	30	-7	49
3	45	8	64
4	41	4	16
5	31	-6	36
6	32	-5	25
7	42	5	25
8	33	-4	16
9	44	7	49
10	37	0	0
11	47	10	100
12	38	1	1
13	39	2	4
14	43	6	36
15	34	-3	9
16	26	-11	121
17	46	9	81
18	28	-9	81
19	25	-12	144
20	48	11	121
	$\sum X = 749$		$\sum(X-\bar{X})^2 = 987$

$$\bar{X} = \frac{\sum X}{N} = 37.4$$

$$SD = \sqrt{\frac{\sum (x-\bar{x})^2}{n}}$$

$$SD = 7.0$$

Calculation of Mean and Standard Deviation for Chemistry Achievement of Low Verbal Reasoning Students.

S/N	Chemistry Achievement of Low Verbal Reasoning Students (X)	$X-\bar{X}$	$(X-\bar{X})^2$
1	15	-7	49
2	20	-2	4
3	14	-8	64
4	25	3	9
5	21	-1	1
6	11	-11	121
7	26	4	16
8	30	8	64
9	31	9	81
10	29	7	49
11	22	0	0
12	23	1	1
13	19	-3	9
14	24	2	4
15	28	6	36
16	17	-5	25
17	27	5	25
18	18	-4	16
19	15	-7	49
20	32	10	100
	$\sum X = 447$		$\sum(X-\bar{X})^2 = 723$

$$\bar{X} = \frac{\sum X}{N} = 22$$

$$SD = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

$$SD = 6.0$$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

t-test value = 7.28

APPENDIX G

Calculation of Mean and Standard Deviation for Chemistry Achievement of High Quantitative Reasoning Students.

S/N	Chemistry Achievement of High Quantitative Reasoning Students (X)	$X-\bar{X}$	$(X-\bar{X})^2$
1	46	6	36
2	47	7	49
3	45	5	25
4	34	-6	36
5	38	-2	4
6	35	-5	25
7	27	-13	169
8	48	8	64
9	44	4	16
10	39	-1	1
11	49	9	81
12	40	0	0
13	43	3	9
14	33	-7	49
15	42	2	4
16	37	-3	9
17	41	1	1
18	36	-4	16
19	50	10	100
20	30	-10	100
	$\sum X = 804$		$\sum(X-\bar{X})^2 = 794$

$$\bar{X} = \frac{\sum X}{N} = 40$$

$$SD = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

$$SD = 7.0$$

Calculation of Mean and Standard Deviation for Chemistry Achievement of Low Quantitative Reasoning Students.

S/N	Chemistry Achievement of Low Quantitative Reasoning Students (X)	$X-\bar{X}$	$(X-\bar{X})^2$
1	20	-4	16
2	25	1	1
3	11	-13	169
4	22	-2	4
5	26	2	4
6	15	-9	81
7	30	6	36
8	31	7	49
9	33	9	81
10	24	0	0
11	23	-1	1
12	19	-5	25
13	28	4	16
14	27	3	9
15	38	14	196
16	16	-8	64
17	34	10	100
18	14	-10	100
19	13	-11	121
20	32	8	64
	$\sum X = 481$		$\sum(X-\bar{X})^2 = 1137$

$$\bar{X} = \frac{\sum X}{N} = 24.05$$

$$SD = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

$SD = 8.0$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

t-test value = 7.14

APPENDIX H

Calculation of Mean and Standard Deviation for Chemistry Achievement of High Non-verbal Reasoning Students.

S/N	Chemistry Achievement of High Non-verbal Reasoning Students (X)	$X-\bar{X}$	$(X-\bar{X})^2$
1	41	2	4
2	45	6	36
3	46	7	49
4	34	-5	25
5	28	-11	121
6	35	-4	16
7	27	-12	144
8	48	9	81
9	44	5	25
10	38	1	1
11	49	10	100
12	39	0	0
13	43	4	16
14	31	-8	64
15	42	3	9
16	36	-3	9
17	47	8	64
18	30	-9	81
19	37	-2	4
20	32	-7	49
	$\sum X = 772$		$\sum(X-\bar{X})^2 = 898$

$$\bar{X} = \frac{\sum X}{N} = 38.6$$

$$SD = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

$$SD = 7.0$$

Calculation of Mean and Standard Deviation for Chemistry Achievement of Low Non-verbal Reasoning Students.

S/N	**Chemistry Achievement of Low Non-verbal Reasoning Students (X)**	X-□	$(X-□)^2$
1	18	-9	81
2	24	-3	9
3	40	13	169
4	22	-5	25
5	25	-2	4
6	29	2	4
7	27	0	0
8	28	1	1
9	35	8	64
10	36	9	81
11	20	-7	49
12	23	-4	16
13	19	-8	64
14	31	4	16
15	30	3	9
16	26	-1	1
17	33	6	36
18	18	-9	81
19	21	-6	36
20	32	5	25
	$\sum X = 537$		$\sum(X-□)^2 = 771$

$$□ = \frac{\sum X}{N} = 27$$

$$SD = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

$SD = 6.0$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

t-test value = 5.83

APPENDIX I

Calculation of Mean and Standard Deviation for Chemistry Achievement of Male Students with High Verbal Reasoning Abilities.

S/N	Chemistry Achievement of High Verbal Reasoning Male Students (X)	X-□	$(X-□)^2$
1	38	0	0
2	43	-5	25
3	36	-2	4
4	42	4	16
5	30	-8	64
6	45	7	49
7	35	-3	9
8	40	2	4
9	34	-4	16
10	39	1	1
	$\sum X = 382$		$\sum(X-□)^2 = 188$

$$□ = \frac{\sum X}{N} = 38.2$$

$$SD = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

$$SD = 4.30$$

Calculation of Mean and Standard Deviation for Chemistry Achievement of Female Students with High Verbal Reasoning Abilities.

S/N	Chemistry Achievement of High Verbal Reasoning Female Students (X)	X-□	(X-□)^2
1	40	2	4
2	43	5	25
3	34	-4	16
4	41	3	9
5	35	-3	9
6	42	4	16
7	37	-1	1
8	44	6	36
9	30	-8	64
10	38	0	0
	$\sum X = 384$		$\sum$(X-□)^2 =180

□= $\frac{\sum X}{N}$ = 38.4

$$SD = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

SD = 4.20

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

t –test value = 0.11

APPENDIX J

Calculation of Mean and Standard Deviation for Chemistry Achievement of Male Students with High Non-verbal Reasoning Abilities.

S/N	Chemistry Achievement of High Non-verbal Reasoning Male Students (X)	$X-\bar{X}$	$(X-\bar{X})^2$
1	35	2	4
2	30	-3	9
3	24	-9	81
4	41	8	64
5	29	-4	16
6	28	-5	25
7	37	4	16
8	42	9	81
9	30	-3	9
10	34	1	1
	$\sum X = 330$		$\sum(X-\bar{X})^2 = 306$

$$\bar{X} = \frac{\sum X}{N} = 33.0$$

$$SD = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

$$SD = 5.50$$

Calculation of Mean and Standard Deviation for Chemistry Achievement of Female Students with High Non-verbal Reasoning Abilities.

S/N	Chemistry Achievement of High Non-verbal Reasoning Female Students (X)	X-□	$(X-□)^2$
1	32	-1	1
2	31	-2	4
3	34	1	1
4	35	2	4
5	33	0	0
6	29	-4	16
7	38	5	25
8	40	7	49
9	28	-5	25
10	34	1	1
	$\sum X = 334$		$\sum(X-□)^2 = 126$

$$□ = \frac{\sum X}{N} = 33.4$$

$$SD = \sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

SD = 3.5

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

t-test value = 0.19

APPENDIX K

Calculation of Mean and Standard Deviation for Chemistry Achievement of Male Students with High Quantitative Reasoning Abilities.

S/N	**Chemistry Achievement of High Quantitative Reasoning Male Students (X)**	X-□	(X-□)^2
1	45	3	9
2	47	5	25
3	42	0	0
4	39	-3	9
5	48	6	36
6	35	-7	49
7	37	-5	25
8	46	4	16
9	40	-2	4
10	38	-4	16
	$\sum X = 417$		$\sum$(X-□)^2 =189

□= $\frac{\sum X}{N}$ = 41.7.0

$$SD = \sqrt{\frac{\sum (x-\bar{x})^2}{n}}$$

SD = 4.30

Calculation of Mean and Standard Deviation for Chemistry Achievement of Female Students with High Quantitative Reasoning Abilities.

S/N	**Chemistry Achievement of High Quantitative Reasoning Female Students (X)**	X-□	$(X-□)^2$
1	48	6	36
2	44	2	4
3	40	-2	4
4	43	1	1
5	45	3	9
6	37	-5	25
7	36	-6	36
8	41	-1	1
9	49	7	49
10	38	-4	16
	$\sum X = 421$		$\sum(X-□)^2 = 181$

$$□ = \frac{\sum X}{N} = 42.1$$

$$SD = \sqrt{\frac{\sum (x-\bar{x})^2}{n}}$$

$SD = 4.2$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

t-test value = 0.05

APPENDIX L

Calculation of the relationship between students' cognitive abilities and their achievement in chemistry.

Cognitive Abilites (X)	Chemistry Achievement (Y)	X^2	Y^2	XY
46	50	2116	2500	2300
41	45	1681	2025	1845
31	35	961	1225	1085
43	46	1849	2116	1978
36	40	1296	1600	1440
47	54	2209	2916	2538
45	53	2025	2809	2385
40	44	1600	1936	1760
26	31	676	961	806
42	43	1764	1849	1806
37	52	1369	2704	1924
39	33	1287	1089	1287
38	42	1444	1764	1596
32	49	1024	2401	1568
44	47	1936	2209	2068
46	48	2116	2304	2208
$\sum X = 633$	$\sum Y = 712$	$\sum X^2 = 25353$	$\sum Y^2 = 32408$	$\sum XY = 28594$

$$r = \frac{N\sum XY - \sum X \sum Y}{\sqrt{[N\sum X^2 - (\sum X)^2][[N\sum Y^2 - (\sum Y)^2]}}$$

$r = 0.70$