ANALYSIS OF SENIOR SECONDARY SCHOOL STUDENTS' EXPERIENCED DIFFICULTY IN SCIENCE PROCESS SKILLS ACQUISITION IN CHEMISTRY

BY

JACK, UZEZI GLADYS

DELTA STATE UNIVERSITY,
ABRAKA

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OCTOBER, 2014

DECLARATION

I, the undersigned, hereby declare that this is an original research work carried out by me in the Faculty of Education, Department of Curriculum and Integrated Science, Delta State University, Abraka, Nigeria. This thesis contains no material that has been submitted previously, in whole or part, for the award of academic degree or diploma. All the sources that l have used or quoted have been indicated and acknowledged by means of complete references.

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Jack, Uzezi Gladys **Date**

CERTIFICATION

We certify that this research work was carried out by **Jack, Uzezi Gladys** and was scrutinized and approved for presentation to the Department of Curriculum and Integrated Science, Faculty of Education, Delta state University, Abraka.

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DEDICATION

This thesis is dedicated to my lovely husband, Pastor John Jack, and my wonderful children: Emmanuel, Esther and Excel Jack.

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First of all, I want to thank the almighty God for keeping me and seeing me through this work, and also for making me possess the aptitude and perseverance to attain my great aim in life.

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Abstract

The general objective of the study was to determine Chemistry students' perceived difficulty in the acquisition of science process skills. Seven research questions and seven hypotheses guided the study. The design adopted for the study was descriptive survey design. The population of the study comprised all senior secondary school III (SS III), Chemistry students in the three senatorial districts of both Adamawa and Taraba States in Nigeria. Seven hundred and twenty (720) respondents were involved in the study through multi-stage random sampling. Twenty students were randomly selected from each of the 36 schools. The research instrument was a test called 'Science Process Skills Knowledge Test in Chemistry' (SPSKTC). The test consisted of Section A which demanded personal information on the school and respondent (bio data); and Section B which consisted of 70 objective questions having 15 items on test of knowledge on science process skills. The items on SPSKTC were extracted from WAECSSCE Alternative to practical Chemistry past questions (2002-2011). The SPSKTC was validated by three experts in science education, two in test and measurement; and two secondary school Chemistry teachers. The data obtained was subjected to Kuder Richardson formula 21 to obtain the correlation coefficient of 0.78, which was considered adequate for the study. The SPSKTC was administered with the help of the Chemistry teachers and the researcher. After the administration of the SPSKTC, students' answers were collected and scored. The percentages, frequencies, means scores and standard deviations were used to collate the data. The level of difficulty of a particular process skill was determined by the value of means as follows: means scores less than 50 (< 50) were classified as difficult, and means scores equal to or above 50 (≥ 50) as simple. The hypotheses were tested using means and t-test at $t \leq 0.05$ level of significance. Hypotheses 1-7 were tested with descriptive t-test statistic using SPSS 16.0 statistical package. Each student was scored on each of the science process skills before the individual scores were aggregated to form a composite score for each student The major findings of the study showed that 12 science process skills (80%) were found difficult by students in acquiring which includes: observing, identifying/controlling variables, inferring, predicting, using number relationships, formulating hypotheses, experimenting, communicating, recording, defining operationally, interpreting data, and classifying; with a total mean scores of 39.35out of the 15 science process skills. The study also indicated that sex, school location and school type have negligible influence on students' acquisition of science process skills; while large class size, students' negative attitude towards Chemistry and laboratory inadequacy have great influence on students' acquisition of science process skills. The study concluded that most students in Nigerian schools experience difficulty in the acquisition of process skills, arising from the persistent use of the lecture method of teaching Chemistry which is not student-activity-oriented. Based on the findings, recommendations were made amongst which are reduction of student-teacher ratio in schools, training of teachers on science process skills and equipping all secondary school laboratories to enable teachers adopt methods that lead students to have the appropriate skills.

CHAPTER ONE

INTRODUCTION

Background of the Study

The shift from the teacher-centred method of teaching science to the student-centred activity based method encourages and develops in the child the spirit of inquiry. The student-centred activity method attempts to make students fully aware, as well as understand the ways scientists work; and also equip and prepare them for possible careers in science and technology and; the development of process skills (Akinbobola, 2006). It is worth noting that for science teaching to be meaningful and relevant, it must adequately reflect the nature of science. That is, it must not only be process-oriented, but it should also emphasize the products of science. It should also promote affective reaction to science and stress attitudes such as honesty, open and critical- mindedness, curiosity, suspended judgment and humility which characterize scientists and the scientific enterprise (Akinbobola and Ado, 2007). Science process skills have been described as mental and physical abilities and competencies which serve as tools needed for the effective study of science and technology, as well as problem solving, individual and societal development (Nwosu and Okeke in Akinbobola and Afolabi, 2010).

The American Association for the Advancement of Science (AAAS) classified science process skills into fifteen. These are: observing, measuring, classifying, communicating, predicting, inferring, using number relationships, using space/time relationship, questioning, controlling variables, hypothesizing, defining operationally, formulating models, designing experiment and interpreting data. According to Valentino (2000), science process skills can be classified into two categories as basic and integrated process skills. The basic (simpler) process skills provide a foundation for learning the integrated (more complex) skills. Basic science processes are vital for science learning and concept formation at the primary and junior secondary school levels. More difficult and integrated science process skills are more appropriate at the secondary and tertiary school levels for the formation of models, experimenting and inference. Hence both basic and integrated science process skills are relevant and appropriate at the senior secondary schools level in Nigeria.

According to Valentino (2000), the basic science process skills comprise observing, measuring, classifying, communicating, inferring, using number relationships, using space/time relationship and questioning while integrated science process skills are controlling and manipulating variable, hypothesizing, defining operationally, formulating models, designing experiment and interpreting data. Chemistry practical skills are science process skills that are taught as part and parcel of the Chemistry curriculum.

Science process skills (SPS) are also defined as the adaptation of the skills used by scientists for composing knowledge, thinking about problems and drawing conclusion (Farsakoğlu,Sahin,Karsli,Akpinar and Ultar, 2008). They are also the abilities each individual is supposed to possess in a science-based community as a science literate person (Temiz, 2007). Ajunwa (2000) observed that science process skills have general commonality in all science subjects, serving as tools for information gathering, problem solving, decision making and adaptation. Science process skills are classified as basic (observing, measuring, classifying, collecting data and using number relationships), causal (predicting, identifying variables and drawing a conclusion) and experimental (formulating hypotheses, making models, experimenting, controlling variables and making a decision) [Ayas,Cepni,Ozmen,Yigit and Ayvaci,2007]. All of these science process skills are complementary of each other, providing students opportunities to reach meaningful learning goals in science.

Science process skills also help in preventing the memorization of facts and developing negative attitudes in science (Temiz, 2007; Dirks and Cunningham, 2006).

Science process skills have great influence on education because they help students to develop higher mental processes such as problem-solving, critical thinking and making a decision (Tan and Temiz, 2003; Koray, Koksal, Ozdemir and Presley, 2007).

Science process skills are cognitive and psychomotor skills employed in problem solving. They are the skills which the sciences use in problem-identification, objective inquiry, data gathering, transformation, interpretation and communication. Science process skills can be acquired and developed through training such as are involved in science practical activities. They are the aspect of science learning which is retained after cognitive knowledge has been forgotten. Using science process skills is an important indicator of transfer of knowledge which is necessary for problem-solving and functional living. The knowledge of process skills in science is very important for proper understanding of concepts in science. Alfredo, Natale and Lombardi (2006) stated that process skills are fundamental to science, which allow everyone to conduct investigation and reach conclusions. They observed that there is a serious educational gap in this area, both in bringing these skills into the classroom and in the training of teachers to use them effectively.

The skills in qualitative and quantitative analysis cannot be completed without creativity. Practical work is not just putting the apparatus together when seen, but it needs planning, designing a problem, creating a new approach and procedure and also putting familiar things together in the new arrangement. This implies that the knowledge of creativity exhibited by candidates in any practical class helps them to manipulate some practical equipment. According to Giddings and Fraser in Akinbobola and Afolabi (2010), achieving the objectives of science practical work depends a lot on the mode of assessment of laboratory work adopted by teachers and examination bodies. According to them, the mode of assessment directly influences teachers' teaching methods, students' learning styles and attitudes towards practical activities.

The West African Examinations Council (WAEC) makes use of practical test/examination to assess students' acquisition of various Chemistry practical skills. In these tests, students are required to carry out certain Chemistry practical activities following given instructions. The scores of the students indirectly indicate the levels of Chemistry practical process skills they could demonstrate during the practical examination. This mode of assessment is also adopted by Chemistry teachers who prepare the students for Senior School Certificate Examination (SSCE). This mode of assessment influences the teaching methods adopted by teachers. Also, students' learning style is influenced in such a way that students always try to find certain correct responses or answers, irrespective of the procedures adopted.

Students are to be made able to acquire scientific knowledge by the processes of thinking, analyzing and interpreting observed facts. A new approach capable of triggering the processes of thinking, analyzing and inferring in the students' mind is needed. Process approach is designed to attain these objectives in teaching science. Process approach presents the instruction in science in an intellectually stimulating and a scientifically authentic way. Here, emphasis is given to the ways of acquiring knowledge rather than to the content. This is a shift from the traditional approach. As a result, outlook on different aspects of instructional practice in science teaching, the designing of instructional objectives and the instructional strategies have changed totally, as also the method of evaluating the results of these processes, i.e. the process outcomes of science teaching. Process approach demands that students utilize their intellect and apply their ability to engage themselves in thinking and reasoning more dynamically. What is actually attained by the process approach is that students are initiated into being scientific investigators themselves. It is also expected to help students become better consumers of scientific knowledge and also enable them to make original scientific contributions to science.

The process approach to teaching science is meant to foster inquiry and manipulative skills in students and discourage rote learning. This approach embraces other methods of science teaching and is mainly activity based, superior to those in which students are not actively involved in the learning process (Akinbobola, 2008). This has made the West African Examinations Council (WAEC) and other bodies that conduct Senior School Certificate Examination (SSCE) to stipulate that practical Chemistry should form the basis of teaching. During examination, practical Chemistry is also assessed separately. Currently, Chemistry being one of the science subjects taught in senior secondary schools is taught both in theory and in practical. In both internal and external examinations, practical Chemistry is assessed separately as an integral part of the subject and students are expected to have acquired certain science process skills on completion of the senior secondary school.

The new science curriculum worldwide stresses science process skills and places emphasis on the development of higher cognitive skills through the student-centred approach (Shulman and Tamir, 2004). This approach, according to Molitor and George (2001) develops the understanding of science process skills through participation of students in activities in science classrooms. Ogunnniyi (2000) opined that the relevance of acquisition of process skills in science teaching is that it involves students' in "doing science". The acquisition of process skills by "doing science" enables students to, understand the concepts of Chemistry easily.

The study by Akpokorie (2000) showed that students experienced difficulty in process skills acquisition in science in secondary schools. Akpokorie (2000) researched on students' experienced difficulty in 15 process skills acquisition in Integrated Science using 600 JS3 students from Delta State and his findings showed that: there are 8 areas of difficulty out of the 15 process skills: these are counting/number relations, communication, prediction, inference, controlling and manipulating variables, experimenting, manipulative techniques (instrument) and building mental models. Moreover, it was found that building mental models was the process skill found most difficult. This was followed by manipulative techniques, controlling and manipulating variables, communication, experimenting, counting/number relations, prediction and inference. The results indicated that students in general did not find the following process skills not difficult which include observation, formulating hypothesis, making operational definitions, measurement, interpreting data and classification, the last one being the simplest. This study contradicts the work of Omajuwa (2011) who found measuring, prediction, communication, classification, raising question, and controlling variables, the last one being the simplest. Both studies also showed that students experienced difficulty more in integrated or higher skills than the basic skills and that sex and school location had no influence on the acquisition of process skills. Series of reports from the chief examiners of WAEC, 2006-2011 and that of Ochu (2007) showed that Chemistry students were deficient in interpreting data, descriptive ability, calculative ability, drawing inference and also in qualitative chemical analysis. It, therefore, follows that the trend is not improving even in recent years.

Despite the importance of Chemistry to mankind and the efforts of researchers to improve on its teaching and learning, the performance of students in the subject remains low in Nigeria. Among the factors that have been identified are class size (Adeyemi, 2008), poor methods of instruction (Millar, Tibergheieri, and Le Marechal, 2002), students' attitude (Yara, 2009), teachers' attitude (Adediwura and Bada, 2007), laboratory inadequacy (Adeyegbe, 2004 and Koray, Koksal, Ozdermir and Presley, 2007), and poor science background (Ugwu, 2007).

Students' attitude towards the learning of Chemistry is a factor that has long attracted attention of researchers. Adesokan (2002) asserted that in spite of realization of the recognition given to Chemistry among the science subjects, it is evident that students still show negative attitude towards the subject, thereby leading to low acquisition of science process skills. Other factors that may influence students' acquisition of science process skills in chemistry include sex, laboratory adequacy, class size, school location and school type. In this study, therefore, attempt was made to find out from the Chemistry students the process skills they had difficulty acquiring. Specifically, this study investigates the influence of sex, school location, school type, class size, students' attitude and laboratory adequacy on students' experienced difficulty in science process skills acquisition in chemistry.

Statement of the Problem

Chemistry is taught in most schools as a bundle of abstractions without practical experiences. This has resulted to students' low acquisition of science process skills which has become more evident in the mass failure of students in the subject in public examinations. All the questions asked to test Chemistry students' knowledge in practical skills require that they demonstrate one form of process skill or the other. The inability of students to carry out these activities properly results in low scores in the test of practical knowledge.

The basic science process skills are useful in science and non-science situations while the integrated skills are the working behaviour of scientists and technologists. Thus, both basic and integrated science process skills are relevant and appropriate for all science subjects, in particular Chemistry at the senior secondary schools. Hence, there is need to find out the level of acquisition of the process skills, including the factors influencing their acquisition; and also to identify the science process skills inherent in the West African Senior Secondary School Certificate (WASSSC) Chemistry practical examination in Nigeria and classify them into various hierarchical levels in terms of students' difficulties. Process skills are very fundamental to science which allows students' to conduct investigations and reach conclusions; but there is still a serious educational gap in this area both in bringing these skills into the classroom and in the training of teachers to use them effectively. Therefore, the problem of this study is: will assess secondary school chemistry students' acquisition on science process skills help in bringing the process skills into the classroom and minimizing difficulty encountered by the students?

Research Questions

The following research questions were raised to guide this study:

1. What specific science process skills do Chemistry students experience difficulty in acquiring?
2. Does sex influence Chemistry students' difficulty in science process skills acquisition?
3. Does school location influence Chemistry students' difficulty in science process skills acquisition?
4. Does school type influence Chemistry students' difficulty in science process skills acquisition?
5. Does class size influence Chemistry students' difficulty in science process skills acquisition?
6. Does students' attitude towards Chemistry influence students' difficulty in science process skills acquisition?
7. Does laboratory adequacy influence Chemistry students' difficulty in science process skills acquisition?

Research Hypotheses

The following research hypotheses were formulated for testing at the 0.05 level of significance:

Ho_1 There is no significant difference in the mean difficulty of chemistry students' scores between basic and integrated science process skills.

Ho_2 There is no significant difference in the mean difficulty of process skills scores between male and female Chemistry students.

Ho3 There is no significant difference in the mean difficulty of process skills scores between Chemistry students in urban and in rural schools.

Ho4 There is no significant difference in the mean difficulty of process skills scores between Chemistry students in single sex and in mixed schools.

Ho5 There is no significant difference in the mean difficulty of process skills scores between Chemistry students in small-class size and in large-class size.

Ho6 There is no significant difference in the mean difficulty of process skills scores between Chemistry students with negative attitude and those with positive attitude towards Chemistry.

Ho7 There is no significant difference in the mean difficulty of process skills scores between Chemistry students who were taught with well-equipped laboratories and those who were taught with ill-equipped laboratories.

Purpose of the Study

The main purpose of this study is to identify secondary school Chemistry students' experienced difficulty in science process skills acquisition. Specifically, the study is designed to achieve the following objectives:

i. Find out the difference in the mean difficulty chemistry students' scores between basic and integrated science process skills;
ii. find out if sex (male or female) influences Chemistry students process skills acquisition.
iii. determine whether the location of a school (urban or rural) influences Chemistry students' process skills acquisition;
iv. determine whether the type of school (single sex or mixed) influences Chemistry students' process skills acquisition;
v. determine whether the class size (small or large) influences Chemistry students' process skills acquisition;

vi. determine whether students’ attitude towards Chemistry (positive or negative) influences Chemistry students’ process skills acquisition; and

vii. determine whether laboratory adequacy (well-equipped or ill- equipped) influences Chemistry students’ process skills acquisition.

Significance of the Study

It is hoped that the outcome of this study should hopefully be of great importance to the following group of persons:

Teachers of Chemistry will make use of the findings of this study to redirect their teaching strategies on the identified difficult science process skills and improve more on students’ activities by using learner-centred methods of instruction to minimize difficulties in process skills acquisition.

Students of Chemistry will also benefit from the findings of the study because it may enable them understand how to acquire science process skills and also know areas of students’ difficulties. This may encourage them to develop and improve on their science process skills.

Principals of schools will also gain from the findings of the study, which may be a useful aid for them as they adopt the process-approach method in their science curricula where students will be actively engaged to learn science.

Curriculum developers will also benefit because the outcome of the study may help them in the planning and designing of the school Chemistry curriculum, especially in the selection of course contents and identification of the specific process skills which students need to acquire.

To the government, the findings of the study will make her see the needs and importance of well-equipped science laboratories in schools for effective teaching and learning of Chemistry.

Finally, information generated from the study will be useful to researchers who may be interested in studying process skills.

Scope and Delimitations of the Study

The study investigated whether class size, laboratory adequacy, students' attitude, sex, school location and school type influence students'difficulties in acquisition of Science process skills. The study focused primarily on assessing secondary school chemistry students' science process skills acquisition in Taraba and Adamawa States of Nigeria. Students used for this study consisted of those in senior secondary school three (SS III) classes in government (public) owned schools.

Operational Definition of Terms

The following terms are operationally defined:

School type: This means either single sex or mixed (co-educational) schools.

Class size: Any class having students above 30 is regarded as large, while a class with 30 students and below is regarded as small.

Laboratory adequacy: Schools having most of the equipment and materials (reagents) for carrying out qualitative and quantitative analysis in their laboratories are regarded as well-equipped, while schools with few or none of these are regarded as ill equipped.

Attitude: Students positive (favourable) or negative (unfavourable) response towards chemistry.

Limitations of the Study

This researcher believes that it may be more effective and reliable if the study is conducted in more than two states in Nigeria. However due to some problems the researcher limits this study only to 36 secondary schools in two states in Nigeria. The problems include: small size samples and lack of cooperation from some of the respondents and teachers. Because of these and other problems the breadth and depth of the study is limited.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter presents a review of works that are related to this study. The review is organized under the following headings:

a) Theoretical framework of the study
b) The concept of process skills
c) The elements of science process skills
d) Developing science process skills
e) Factors influencing the acquisition of science process skills
f) Students' difficulties in science learning and process skills acquisition
g) Empirical studies on science process skills acquisition
h) Empirical studies on students' attitude, laboratory adequacy, class size, gender, school location, and school type
i) Appraisal of the review

Theoretical Framework of the Study

Curriculum statements recommend that teachers should adopt instructional strategies that would facilitate the meaningful learning of science by engaging learners in authentic activities that reflect how scientific knowledge is developed. To this end, the Biological Science Curriculum Studies (BCSC, 1993) prescribed an instructional model of teaching and learning science and for the acquisition of process skills. This model of instruction is referred to as constructivism, a term that expresses a dynamic and interactive conception of human learning. It has also been observed that the type of curriculum designed for Nigerian schools is the spiral curriculum and the constructivism approach to spiral curriculum provides that children should learn by discovering things for themselves (Adikwu, 2008).

The theoretical framework for this study is hinged on constructivist learning theory that was propounded by Bruner (1960) which is based on active learning. Bruner's constructivist learning theory is a general framework for instruction based upon the study of cognition. He advocated discovery-based instruction in which teachers provide situations that let students discover ideas for themselves. Much of the theory is linked to child development research (especially Piaget). A major theme in the theoretical framework of Bruner is that learning is an active process in which learners construct new ideas or concepts based upon their current/past knowledge. The learner selects and transforms information, constructs hypotheses, and makes decisions, relying on a cognitive structure to do so. Cognitive structure (i.e., schema, mental models) provides meaning and organization to experiences and allows the individual to "go beyond the information given". As far as instruction is concerned, the instructor should try and encourage students to discover principles by themselves. The instructor and student should engage in an active dialog (i.e., Socratic learning). The task of the instructor is to translate information to be learned into a format appropriate to the learner's current state of understanding. Curriculum should be organized in a spiral manner so that the student continually builds upon what they have already learned. Bruner (1966) states that a theory of instruction should address four major aspects: (1) predisposition towards learning, (2) the ways in which a body of knowledge can be structured so that it can be most readily grasped by the learner, (3) the most effective sequences in which to present material, and (4) the nature and pacing of rewards and punishments. Good methods for structuring knowledge should result in simplifying, generating new propositions, and increasing the manipulation of information.

Constructivism sees learning as a dynamic and social process in which learners actively construct meaning from their experiences in connection with their prior understandings and the social setting. The constructivist view of learning argues that students do not come to the science classroom empty-headed but arrive with lots of strongly formed ideas about how the natural world works. In the view of constructivists, pupils should no longer be passive recipients of knowledge supplied by teachers and teachers should no longer be purveyors of knowledge and classroom managers (Fosnot, 1996). From this perspective, learning is a process of acquiring new knowledge, which is active and complex. This is the result of an active interaction of key cognitive processes. It is also an active interaction between teachers and learners, and learners try to make sense of what is taught by trying to fit these with their own experience.

Constructivist views also emphasize generative learning, questioning or inquiry strategies (Driver, 1989). An emphasis on constructivism and hands-on inquiry-oriented instruction to promote children's conceptual knowledge by building on prior understanding, active engagement with the subject content, and applications to real world situations has been advocated in science lessons (Stofflett and Stoddart, 1994). Constructivist views emphasizing discovery, experimentation, and open-ended problems have been successfully applied in science (Von Glaserfield, 1989). Wheatley (1991) believed that good science teachers are those who teach for deep understanding, and they use students' ideas about science to guide lessons, providing experiences to test and challenge those ideas to help students arrive at more sophisticated understanding. The classrooms of such teachers are learner-centred places where group discussion, exploration and problem solving are common place.

In constructive learning setting, the students are to be made to acquire scientific knowledge by the processes of thinking, analyzing and interpreting observed facts. This mode of learning is embedded in the process approach which is capable of triggering the processes of thinking, analyzing and inferring in the students' mind. The Process approach which is rooted in constructivism is designed to attain these objectives in teaching science. The process approach presents the instruction in science in intellectually stimulating and scientifically authentic way. Here emphasis is given to the ways of acquiring knowledge rather than to the content. This is a shift from the traditional approach. As a result, outlook on different aspects of instructional practice in science teaching, the designing of instructional objectives and the instructional strategies has changed totally, as also the method of evaluating the resultant of these processes, i.e. the process outcomes of science-teaching. Process approach demands of the students to utilize their intellect and apply their ability to engage themselves in thinking and reasoning more dynamically. What is actually attained by the process approach is that the students are initiated into being scientific investigators themselves. It is also expected to help the students become better consumers of scientific knowledge and it would enable them to make original scientific contributions to science. According to Hurd (1971) science is an intellectual activity, which arises from personal experience and takes place in the mind of man. There are certain operational schemes in the field of science characterizing its investigative nature e.g. inquiry skills or processes of science. The processes represent the intellectual means by which man inquiries into nature, i.e., organizes his observation; establishes data; focuses it on a problem: and this seeks to interpret or explain the rational event.

UNESCO (1971) referring to process approach in science, makes the following comments:

a. An emphasis on process implies a corresponding de-emphasis on specific science content.

b. What is taught to children should resemble what scientists do – the processes that they carry out in their scientific activities.

c. Processes are in a broad sense 'ways of processing information' - intellectual skills. The processes are: observing, classifying, using numbers, measuring, using space time relationship, communicating, predicting, inferring, defining operationally, formulating hypothesis, interpreting data, controlling variables and experimenting.

UNESCO (1992) summarises the process skills of primary school children as: Observing, raising questions, hypothesizing, predicting, finding patterns and relationships, communicating effectively, devising and planning investigations, designing and making, manipulating materials and equipment effectively, measuring and calculating

Anderson et al.(2001) describe science as 'an accumulation of systematised facts'. The operational definition of science, they state, is as follows: "It is the activity through which scientists solve problems by using scientific method." The main steps of this activity are: a problem is stated; a hypothesis is formulated; an experiment is conducted; data are collected; and a conclusion is drawn.

For students' to be actively engaged for effective teaching and learning in constructivist science classrooms, Brooks and Brooks (1993) specify some guiding principles which includes: 1) posing problems of emerging relevance to students, 2) structuring learning around primary concepts, 3) seeking and valuing students' points of view, adapting curriculum to address students' suppositions, 4) assessing student learning in the context of teaching. Constructivist classrooms implementing the guiding principles rely heavily on primary sources of data and manipulative materials; view students as thinkers with emerging theories about the world; seek students' points of view in order to understand students' present conceptions; and involve students in group work. Constructivist teachers encourage student inquiry by asking thoughtful, open-ended questions and encouraging students to ask questions of each other (Brooks and Brooks, 1993).

Brooks and Brooks (1993) offered an interesting comparison of the visible differences between the traditional and the constructive classroom.

Table 2.0: Comparison of Traditional and Constructive classrooms

Traditional classroom	Constructive classroom
Student primarily work alone	Student primarily work in groups
Curriculum is presented part to whole, with emphasis on basic skills (bottom-up)	Curriculum is presented part to whole, with emphasis on the big top concept(top-bottom)
Curricular activities rely heavily on textbooks of data and manipulate materials.	Curricular activities rely heavily on primary sources.
Strict adherence to a fixed curriculum is highly valued.	Pursuit of student questions is highly valued.
Students are viewed as "blank slates" onto	Students are viewed as thinkers with

which information is etched by the teacher.	emerging theories about the world.
Teachers generally behave in a didactic manner, disseminating information to students.	Teachers generally behave in an interactive manner mediating the environment for students.
Teachers seek the correct answers to validate students' lessons.	Teachers seek the students' point of view in order to understand student learning for use in subsequent conceptions.
Assessment of student learning is viewed as separate from teaching and occurs almost entirely through testing.	Assessment of student learning is interwoven with teaching and occurs through teacher observation of students at work and through exhibitions and portfolios.

Source: (Brooks and Brooks, 1993)

Students' success in science (Chemistry) according to Carl (2003) depends on teaching and learning as an active inquiry process. The first step according to Valentino (2000) in implementing a skills-based approach to science instruction begins by carefully defining what you would like the students to be able to do. This means that all teachers need the opportunity to teach science as something in which students are actively engaged which facilitates students' acquisition of Science process skills. The American Association for the Advancement of Science (AAAS, 1971) presents thirteen skills (scientific skills) which are learner–activity centred. They are as follows: basic skills (observing, using space/time relationship, classifying, using numbers, measuring, communicating, predicting, inferring; and integrated skills (controlling variables, interpreting data, formulating hypothesis, defining operationally and experimenting). All these process skills which are complementary to one another can be acquired effectively in constructivist classrooms were the students are actively engaged.

The Concept of Science process skills

The search for a more effective approach for the teaching and learning of Chemistry that will enhance the acquisition of process skills has persisted over the years. This is because; the acquisitions of science process skills are the bases for scientific inquiry and the development of intellectual skills and attitudes that are needed to learn concepts. Nwosu in

Ibe (2004) asserted that science process skills are abilities which can be developed by experience and used in carrying out mental and physical operations. According to Ibe (2004), the American Association for the Advancement of Science (AAAS) developed a programme known as ‘Science A-Process Approach’ (SAPA). This programme sees science processes as true essence of science. The programme was designed to improve children’s skills in the process of science. Ajunwa (2000) reported that science educators and curriculum experts modified them by either expanding or condensing them to suit their special needs or expectations. The Nigerian Educational Research Council in 1990 therefore, modified and came up with fifteen (15) science process skills. These are: i. Observing ii. Measuring iii. Classifying iv. Communicating v. Defining operationally vi. Predicting vii. Controlling Variables viii. Hypothesizing ix. Questioning x. Inferring xi. Using space/time relationship xii. Designing experiment xiii. Interpreting data xiv. Formulating models xv. Using number relationship.

Realizing the importance of science process skills as solution to scientific problems, the Federal Government, among other things, states as one of the national goals of education in Nigeria that: “education should aim at helping the child in the acquisition of appropriate skills, abilities and competencies, both mental and physical as equipment for the individual to live in and contribute to the development of the society” (Federal Republic of Nigeria (FRN), 2004:29). In order to realize this goal, associations, such as Science Teachers Association of Nigeria (STAN) and Nigerian Integrated Science Project (NISP) were set up by the government to look into the various curricula used at various levels of Nigerian educational system. The various curricula developed, have their objectives which have to be achieved for a successful science education and attainment of the national goals and aspirations. These goals and aspirations cannot be realized except through the effective effort of the classroom teacher.

According to Nwagbo (2001), a number of factors have been identified as contributing to the non-acquisition of skills by secondary school students which invariably lead to poor performance and one of the factors is the teacher variable, that is, the teachers' method of teaching. Furthermore, Okoli in Nwagbo (2006) indicated that many science teachers prefer the traditional expository/lecture method of teaching that is, a teaching technique in which one person, the teacher, presents a spoken discourse on a particular subject and shy away from activity-oriented teaching methods which are student centred (such as inquiry method, discovery method, investigative laboratory approach). Nwagbo (2006) observed that such teacher-centred approach which places the teacher as the sole possessor of knowledge and the students as passive recipients of knowledge may not promote positive attitude of students' to science subjects which includes Chemistry.

Science learning is expected to produce individuals that are capable of solving their problem as well as those of the society. Such individuals are expected to be autonomous, confident and self-reliant. Science and technology constitute the basis of advancement in nearly all fields of human endeavours. Obiekwe (2008) reported that all is not well with science instruction in Nigerian secondary schools, and noted that science teaching lays extreme emphasis on content and the use of "chalk and talk" method, neglecting the practical activity method which enhances teaching and learning. This negligence and 'shy-away' attitude from activity oriented- method of teaching has led to abstraction which makes the students less active and more prone to rote memorization. Based on this, the Federal Government of Nigeria is emphasizing "the teaching and learning of science process and principles which will lead to fundamental and applied research in the sciences at all levels of education" (FRN, 2004: 29).

Learning Chemistry goes beyond science knowledge acquisition since it includes the acquisition of cognitive skills such as the, science process skills. Science process skills are the foundation for scientific inquiry, where knowledge is developed inductively, from sensory experience (Gagne, 1963 cited in Saat and Kamriah, 2005). Chemistry practical skills are science process skills and students' need to acquire and develop them for effective and sustainable development in science and technology.

The place of science process skills is prominent and important to teaching ways of reaching knowledge. The students need the process skills both when doing scientific investigations and during their learning process (Harlen, 2000; Taconis, Ferguson-Hessler and Broekkamp, 2000). For these reasons, students should be informed about the importance of science process skills.

Science process skills (SPS) are defined as the adaptation of the skills used by scientists for composing knowledge, thinking of problems and making conclusions. As a society, the goals is for each individual to be scientifically literate (MNE, 2006; Temiz, 2007). Çepni et al. (1997) also defined Science process skills as facilitating basic activities in regards to learning science, gaining research method and techniques, helping students to be active and to make learning permanent. Science process skills are classified as basic (observation, testing, classification, relating number with space, and recording data), causal (prediction, determination of variables, and drawing a conclusion) and experimental (making a hypothesis, modelling, doing the experiment, changing and testing the variables, and making a decision) (Ayas et al., 2007; Kanlı and Yağbasan, 2008).

Science process skills ensure that students have the meaningful learning experience. Science process skills has a great influence on science education because they help students to develop higher mental skills, such as critical thinking, making decision and problem solving (Lee, Hairston, Thames, Lawrence and Herron, 2002; Tan and Temiz, 2003; Arslan and Tertemiz, 2004; Koray, Köksal, Özdemir and Presley, 2007).

Many researchers have investigated studies related to science process skills in science education (Beaumont-Walters and Soyibo, 2001; Huppert, Michal, Lazarowitz, 2002; Tan and Temiz, 2003; Harrell and Bailer, 2004; Saat, 2004; Monhardt and Monhardt, 2006). Some recent studies indicated that the laboratory practices had great influence to increase students science process skills (Aydoğdu, 2003; Tatar, Korkmaz and Şaşmaz Ören, 2007; Kanlı and Yağbasan, 2008). What attracts the researchers' attention is the small number of studies carried out on the science process skills of teachers and prospective teachers (Farsakoğlu, et al, 2008; Karslı, Şahin and Ayas, 2009). In their study, Farsakoğlu et al, (2008) determined that senior prospective teachers explaining science process skills theoretically had difficulties when transferring the theoretical knowledge into the practical applications and confused it with concepts like Bloom's Taxonomy and Piaget's Formal Operation Stages. Considering that teachers are the main source in educating individuals, it is inevitable that there is a need for current teachers and prospective teachers to possess science process skills.

Science process skills are used in real life as well as in science. Students are required to explain how real life events occur. Science process skills involve creativity and critical thinking along with scientific thinking. It is known that those who can think creatively and critically are an important factor in the development of a country. Aktamış and Ergin (2007), aimed to determine the relationship between Science process skills and scientific creativity, and they found a meaningful correlation between the two. Therefore, it is possible to say that Science process skills can be thought as a measurement of creativity in making scientific discoveries and contributing to countries' development. In order to scientifically educate creative individuals, it is necessary to improve students' Science process skills. Teachers play an important role for teaching Science process skills to students through arranging learning activities, determining the development of students' Science process skills and teaching how to reach scientific information (Ash, 1993; Harlen, 1999; Bağcı Kılıç, 2003; Arslan and Tertemiz, 2004). Prospective Science Teachers should be encouraged to design activities aiming to improve their students' science process skills development in the future.

The modern science curriculum materials are discovery and inquiry- oriented. In discovery teaching, a student works out in his mind some concept or principle. In the process of discovering, an individual performs such mental operation as: measuring, predicting, observation, inferring, classifying, describing, and so on. In inquiry an individual may use all of the process skills such as: formulating problems, hypothesizing, designing experiments, operational definitions and such attitudes as objectivity, curiosity, open-mindedness, respect for theoretical models, and so on.

Discovery and inquiry teaching may vary from a relatively structured approach where considerable guidance is provided by the instructor to free investigation where the students originate the problems. These methods increase intellectual potency, shift from extrinsic to intrinsic rewards, help students learn how to do things in investigative ways, increase memory retention, make instruction student centred, build self- concepts, increase expectancy levels, develop only on the verbal, and permit more time for students to assimilate and accommodate information.

Research indicates that students taught by these approaches perform significantly better on cognitive tasks involving critical thinking than those taught traditionally (Millar et al., 2002, Oraifo, 2003; Lanka, 2007). Student- activity centred approach in the science classroom involves students' mental processes, such as observing, classifying, measuring, inferring, and so on they can also draw general conclusion from accumulated facts.

The Malaysian primary science syllabus has given due emphasis to the acquisition of both basic and integrated science process skills. There are 12 skills outlined in the syllabus.

The skills of observation, classification, measurement and using numbers, time and spatial relationships, making inference, prediction and communication are categorized as the basic science process skills. While the skills of controlling variables, interpreting data, defining operationally, formulating hypotheses and experimentation are categorized as the integrated science process skills (Saat and Kamriah, 2005).

Moreover, the Botswana General Certificate of Education (BGCSE) course work scheme of assessment in the sciences is categorized into four skill areas as shown in the work of Lanka (2007), as follows:

Skill C_1: Using and organizing techniques, apparatus and materials;

Skill C_2: Observing, measuring and recording;

Skill C_3: Interpreting and evaluating experimental observations and data;

Skill C_4: Planning, carrying out and evaluating investigations.

The four skill areas comprise both cognitive and manipulative skills and abilities in which learners are expected to show competence. The challenge of science teachers is to plan for learners opportunities to learn Chemistry content through such methods as inquiry, demonstration, practical work, project work, case study, field trips, discussions, computer guided learning, and so on (Lanka, 2007).

The work of Keys and Bryan (2001) revealed that science processes and skills can be developed by engaging learners in authentic learning activities. These are activities that should provide learners with opportunities to formulate scientific problems and design investigations for solving these problems. This requires teachers to adopt inquiry-based approaches to science teaching and learning. Inquiry teaching and learning is well documented by the National Research Council (NRC) in the USA. For example, the NRC suggested five essential features of inquiry for the learner:

i. engages in scientifically oriented questions;

ii. gives priority to evidence in responding to questions;
iii. formulates explanations from evidence;
iv. connects explanations to scientific knowledge;
v. communicates and justifies knowledge explanations (NRC, 2000).

The NRC further elaborated on a typology of school laboratory experiences, which include the following:

i. posing and research question;
ii. using laboratory tools and procedures;
iii. handling materials safely and making measurements;
iv. formulating hypotheses;
v. designing investigations;
vi. making observations, gathering and analyzing data;
vii. building or revising models; and
viii. evaluating, testing or verifying explanatory models (including known scientific theories and models) (NRC, 2006).

It has been observed that these essential features introduce important aspects of science to students while simultaneously assisting them in developing knowledge in regard to specific science concepts (Smolleck, Zembal-Saul and Yodder, 2006). Thus, science teachers should have the necessary knowledge and skills for planning and executing learning experiences that will expose learners to inquiry experiences, thereby allowing them to apply both cognitive and manipulative processes in solving scientific problems. Contemporary research suggested that teachers can acquire their knowledge for teaching from: subject-matter knowledge, pedagogical knowledge, context knowledge, knowledge of learners, and so on. These combine to form what is known as pedagogical content knowledge (PCK), which has been widely acknowledged as the essential component of teacher knowledge that influence teachers' action in the classroom (Lanka, 2007). This implies that teachers should have an understanding of how to represent subject matter in a manner appropriate with the nature of the subject they are teaching and take into consideration the cognitive levels and abilities of their learners.

In the case of teaching science process skills, science teachers should have the necessary knowledge for inquiry-based teaching and learning, and how to represent inquiry activities to the learners. Keys and Bryan (2001) argued that teachers who use an inquiry approach must have rich and deeply developed understandings of science content, student learning, the nature of science, and ways to engage students in investigative practices. The new methodology of science teaching has shifted from concern for "processes of imparting knowledge" to "processes of learning through individual investigation". This has made most government funded science programs for primary and secondary schools over the last decade to stress students' involvement in discovery and/or inquiry oriented activities. In inquiry or discovery activities, students' through their mental processes, such as observing, classifying, measuring, inferring, and so on, can draw general conclusion from accumulated facts.

The processes of learning through individual investigation such as observing, measuring, classifying, inferring, predicting, communicating, interpreting data, used in solving problems, and so on make up the processes of science. The activities involved in collecting data, analyzing, and interpreting and or processing information generally require abilities. These highly specialized activities are seen as skills. The processes of science are therefore accomplished by means of skills.

Kempa and Ward gave a four-phase taxonomy that describes all processes of work in science education. These include:

> *Planning and designing an investigation which requires that students should predict results, formulate hypothesis and design procedure………. experiments which entails decision making by the student about investigative techniques and manipulation of material and equipment,*

observation……….analysis, application and explanation in which data processing, discussion of results……….relationship and formulation of new question and problems carried out by the student (Kempa and Ward,1975 cited in Akpokorie, 2000).

Another classification by Klopfer, (1971) cited in Akpokorie, (2000) include skills of:

i. recognizing and detaining problems;
ii. recognizing assumptions;
iii. formulating working hypotheses;
iv. selecting suitable test for hypotheses;
v. designing appropriate procedures for hypothesis testing or performing experiments;
vi. recognizing and processing experimental data;
vii. describing and/ or reporting observations;
viii. manipulating variables; and
ix. generalizing and applying generalizations.

Nwosu and Okeke (1995) see science skills as the skills and strategies both mental and physical, that scientists use to carry the process of doing science. These skills have the enduring quality of enabling the individual in acquiring and processing information, and solving problems even when the information base changes. These process skills are the foundation for both scientific inquiry and development of intellectual skills needed to learn concepts. These skills can help an individual to grow into an autonomous confident thinking and can also take some responsibilities for shaping positive lives as well as that of the society. It is obvious that any meaningful learning of science by students must include the acquisition of the science process skills and, science curricular worldwide were modified to reflect this emphasis.

Elements of Science process skills

The science process skills were derived from the process approach which is typified by the American Association for Advancement of Science (AAAS) Scheme for primary school science. The approach capitalizes on the mental processes and skills which are common to various discipline particularly sciences subjects. The learner is also encouraged to behave like a mature learner performing the kinds of tasks which lead to reflective thinking, and which discovers knowledge through the use of scientific method of inquiry. Science process skills are basic skills of inquiry that are used throughout the science curriculum.

The development of science process skills in pupils provides as essential component of the achievement of the goals of general education even if the child does not continue his studies in the particular subject. The manner of thinking already inculcated becomes a basic repertoire of his general problem- solving skill for life (Gbamanja, 1991).Thirteen (13) process skills were evolved from the national survey conducted by the American Association for the Advancement of Science (AAAS) of what scientists claim to do. The Nigerian Educational Research Council (NERC) while adopting these processes modified them into 15 processes as a basis for building the Nigerian Primary School Science Curriculum; and also forms an integral part of science teaching at all levels of education.

The science process skills as recommended by NERC (1971) and from the works of Gbamanja(1991) and Akpokorie (2000) are discussed briefly:

1. **Observing**

Observing is the fundamental science process skill. In this process of science, there is the use of the five senses in various ways to determine the quality and quantity of things observed which should be detailed and accurate written. The teacher guides the students to manipulate or display objects in order to expose their properties. The teacher ensures that students involve in making observations.

Observations may have varying complexity, which to make good observations is also essential to the development of the other science process skills: communicating, classifying, measuring, inferring, and predicting. The simplest observations, made using only the senses, are qualitative observations. Observations that involve a number or quantity are quantitative observations. Quantitative observations give more precise information than our senses alone.

Using your senses to gather information about an object or event is qualitative data. The teacher should guide the students to:

i. observe the details of objects with all the senses;

ii. determining the properties of an object or event by using the senses; and

iii. make observations from primary sources in order to attain primary experiences and reflective thinking.

2. Measuring

Standardized units are used to compare the properties of objects or phenomenon. Using standard measures or estimations to describe an object or event is quantitative data. The use of the number makes a measurement a quantitative observation. Certain variables for example, height, length, width, area, volume, time are utilized for ease of comparison or communication. The teacher should guide the student to:

i. identify the physical properties or variable to be measured;

ii. catalogue objects on the basis of the level, intensity or magnitude of observed properties;

iii. use measuring device effectively where their use is applicable;

iv. use standard units for effective communication; and

v. estimate these physical properties in situations where measuring devices are not available or cannot be improved.

3. Counting Numbers

This skill involves use of discreet numbers in association with units of measures such as 2 beakers, 4 test tubes, and 1 pipette and so on. It may involve addition, subtraction, multiplication and division. This skill is taught in mathematics but can be practiced in other disciplines as well. Counting makes for precision in observations and must be applied in all scientific activities. The teacher should guide the students to:

i. make accurate and precise observations;
ii. describe quantitatively using appropriate units of measurement; and
iii. estimate and record accurately using number relationships.

4. Classifying

Classification involves ordering or grouping objects or events into categories based upon characteristics. Using scheme from observation and measurement objects or events can be grouped by imposing order based on similarities, differences, and interrelationships for better understanding.

There are several different methods of classification. The simplest method is serial ordering, where objects are placed into rank order based on some property e.g. height. Two other methods of classification are binary classification and multistage classification. In binary classification, a set of objects is simply divided into two subsets e.g. animals can be classified into two groups: those with backbone and those without backbones; while multi-stage classification is constructed by performing consecutive binary classifications on a set of objects and then on each of the ensuring subsets resulting in layers or stages e.g. Plant and Animal Kingdoms.

In leading the students to classify, the teacher has to create the atmosphere for them to:

i. observe carefully the objects or phenomena to see their similarities and difference;
ii. group these objects or phenomena on the basis of the observed similarities;
iii. make use of units of measurement in the grouping objects to group them, for example acids and bases; and
iv. communicate the similarities and difference on the basis to grouping is done.

5. Inferring

This is a higher-order process because it is based on evaluation and judgment which belong to both cognitive and affective domains in the taxonomy of educational objective. Based on observation, inferring involves making some possible explanations.

Observation leads to inference which can form the basis to further observation leading perhaps, to the modification of the original inference. Inferences are explanations or interpretation that follows from observations.

Observation→ Inference→ Observation → Inference Modified

The teacher’s task here is to guide the students to be able to:

i. see most inference as coming from observation (cause-effect relationship);

ii. select observation for making inference;

iii. make inference on the bases of observation;

iv. see inference as the bases for planning for more observation; and

v. accept the effect of experimental errors on inferences.

6. Predicting

Prediction involves suggesting the most likely outcome of a future event based upon previously collected evidence. In making predictions, past observation and inference are applied to forecast or formulate results. Prediction is based on both good observation and inferences made about observed events. Accurate observations are therefore needed to make dependable prediction: prediction as a process of science according to Akpokorie (2000) is very important because in scientific investigation, there is higher emphasis on making predictions about events and phenomena than describing or explaining them. The teacher should guide the student to:

i. predict using observation and inference;

ii. make use of quantitative results in measuring to predict;

iii. understanding the place of specifying experimental conditions in making prediction;

iv. make explanation on the bases of the same experimental conditions; and

v. communicate past experience (observations) which prediction is made to boost confidence in the prediction.

7. Communicating

Communicating involves using drawings, words, numbers, or graphs to describe an event or object. Observations in science are not meaningful unless they are communicated. Accurate records of experimental results should be kept. Graphical representations, charts, maps, visual demonstrations and diagrams if used along with write-ups can make for precision and clarity. The teachers’ tasks in developing these skills include helping the students to:

i. state the experimental problems;

ii. outline the conditions for observation;
iii. write down the observation made;
iv. organize data got from measuring;
v. make charts, draw diagrams and graphs; and
vi. describe briefly various steps taken in the experiment.

8. Interpreting Data

This process is aimed at providing answers to the questions or hypotheses being investigated. Various data collected through the use of the processes already described are analyzed as a means of finding solution to the initial problem. Acquired data to be interpreted are collected from both qualitative and quantitative data during an investigation. The teacher should guide the students to:

i. gather data that will help answer the question;

ii. describe relationship in graphs, charts and diagrams;

iii. discuss information contained in graphs, chart and diagrams;

iv. support inference on the basis of data interpreted; and

v. form concepts using data interpretation and other processes treated so far.

9. Raising Questions

Questions are problems to be solved using the processes of science. To solve any problem, the investigator or problem solver needs to ask questions to ask questions. To raise questions is a basic skill which grows from observation. As the individual observes keenly he is liable to see avenues for analysis and criticisms regarding the object observed. Analysis and criticisms will lead to questioning which subsequently will lead to clarification and understanding. The learner therefore must be trained not to be a passive listener but an active participant in questioning how, when and why things happen, or why certain objects are what they are. The learner must be trained to ask appropriate questions that lead to relevant answers. The teacher should give the students to:

i. identify the variables;
ii. state the problem in question form; and
iii. make distinctions between empirical and theoretical questions.

10. Formulating Hypotheses

Formulating hypotheses involves suggesting the outcome of an experiment. Hypotheses are statement of research questions put in testable forms. They may be statement of relationship between two or more variables it is a guess or an assumption which will later be verified. Hypothesis is a different from a prediction in the sense that a prediction has more element of certainty because it is usually based on available evidence. Science teachers are encouraged to make tentative intelligent guesses which can later be investigated. Formulating hypothesis is an important step to the learner. The teacher should guide the students to:

i. formulate Hypotheses in a testable form; and
ii. identify the variables of an investigation.

11. Making Operational Definitions

Operational definitions are necessary to focus the attention of the student phenomena being investigated by the students may be occurring frequently. In carrying out investigation, a situational definition is tentatively given to the phenomena. The definition can be done solving mathematical relationship. The teachers' tasks here include guiding the students to:

i. understand the difference between operational definition and any other type of definition;
ii. accept operational definition as being tentative;
iii. sort out observation necessary for operation;
iv. state experimental conditions for investigating the tentative definition; and
v. use mathematical relationship where possible to make operational definition.

12. Formulating Models

Formulating models involves seeing patterns in data and developing analogies to common experiences. A model according to Gbamanja (1991) is a physical representation of explanation that sums up, or portrays an observation made before. These models are used to predict what could happen in another set of similar observation or circumstances. With the evolutions of new evidence which could challenge various facets of the models, a revision may be added in the models to accommodate the new observation. But, models could also take the form of pictures, maps, flow charts, graphs and all types of visual materials that help to improve and facilitate learning. Generally, two or three dimensional models of objects, situations or related events make understanding easier and more permanent than verbal descriptions. Models and operational definitions therefore go together and these increase the retention rate in the learner. The teacher should guide the students to:

i. formulate models so as to make concepts clearer; and
ii. use concrete models to facilitate formation of mental models and concepts.

13. Experimentation

Experimenting involves carrying out a repeatable investigation. Experimentation is the basic ingredient in acquiring scientific information. Scientific hypotheses are followed up and verified through experimentation. Scientific knowledge is accepted only if it has been verified through relevant experimentation. Experimentation involves the scientific method of testing hypothesis which was formulated based on observations. The teacher should guide the students to:

i. seek information using experimental procedures such as observations, interpretation of data, questioning, investigating and confronting the unknown;

ii. investigate and explore further into their environment by exposing them to a wide range materials; and

iii. verify the abstract knowledge taught in class so that they can experience the knowledge in more concrete terms.

14. Controlling Variables

A variable is an event, happening, phenomena or anything that can change and affect the result of an experiment or investigation. In all experiments or investigation, to produce the same type of results, the numerous variables that may be involved must be controlled and kept constant. Skill in controlling variables can assist the learner identify and control variables in problem situations affecting his life.

Identify the Variables by stating the elements of an experiment that can be changed to affect the outcome. The variable you want to test should be the only one that changes. The other variables should be controlled. The name of the variable you change is the independent variable, and the name of the one you measure is the dependent variable. All variables that are kept the same is the controlled variables or constants.

Variables should be defined operationally by explaining how you will measure a variable in an experiment. The relationships between variables should be described by explaining how dependent and independent variables relate to one another and how you will compare them. The teacher should guide the students to:

i. identifying the variables in a situation;
ii. set up/control experiments, to identify and control variables that may affect results; and
iii. select variables to be manipulated and held constant.

15. Manipulation

Manipulation is an important skill that must be developed in students in all disciplines particularly those that would involve in handling of objects or living things. The skill to manipulate or handle breakables, poisonous, dangerous, or expensive equipment can save students from accidents, waste and even accidental death. Manipulation requires the use of manual dexterity which is a skill used especially in handling things. The teacher should guide the students to:

i. manipulate or handle things/objects in the laboratory; and
ii. manipulate data from observed phenomena either collected by self or by others, in order to make meaningful information.

Successfully integrating the science process skills into classroom lessons and field investigations will make the learning experience richer and more meaningful for students. Students will be having the skills of science as well as science content. The students will be actively engage with the science they are learning and thus reach a deeper understanding of the content. Finally acting engagement with science will likely lead students to become more interested and have more positive attitudes towards science.

Developing Science process skills

Discovery-learning is the most effective way for students to acquire the skills and concepts necessary to become scientifically literate adults. However, many classrooms are still struggling to build a discovery-based science curriculum.

There is an urgency today that makes acquiring science process skills of great importance**.** Benchmarks for Science Literacy emphasizes the importance of skills development in preparing students to "make their way in the real world, a world in which problems abound: in the home, in the workplace, in the community and on the planet"(Valentino, 2000). In this technological age, knowing how to acquire and evaluate information and how to use it to understand and solve problems is a prerequisite for most jobs the students will have as adults.

The first step, according to Valentino (2000), in implementing a skills-based approach to science instruction begins by carefully defining what you would like the students to be able to do. Discovery Works according to Valentino (2000) organizes science skills into three separate groups: Process Skills, Reasoning Skills, and Critical Thinking Skills. These groups correspond to three distinct types of cognitive skills. Process skills are used to gather information about the world. Reasoning skills help children make sense of the information they gather by fostering an open mind, curiosity, logic, and a data-based approach to understanding the world. Critical thinking skills require students to apply information in new situations and in solving problems.

Table 2.1: Science process skills

Science process skills	
Skill	**Description**
Observing	Determining the properties of an object or event by using the senses
Classifying	Grouping objects or events according to their properties
Measuring/Using Numbers	Describing quantitatively using appropriate units of measurement, Estimating, Recording quantitative data, Space or time relationships
Communicating	Using written and spoken words, graphs, tables, diagrams, and other information presentations, including those that are technology based
Inferring	Drawing a conclusion about a specific event based on observations and data; may include cause and effect relationships
Predicting	Anticipating consequences of a new or changed situation using past experiences and observation
Collecting, recording and interpreting data	Manipulating data, either collected by self or by others, in order to make meaningful information and then finding patterns in that information that lead to making inferences, predictions and hypotheses
Identifying and Controlling Variables	Identifying the variables in a situation; selecting variables to be manipulated and held constant
Defining Operationally	Defining terms within the context of one's own experiences; stating a definition in terms of "what you do" and "what you observe"
Making Hypotheses	Proposing an explanation based on observations
Experimenting	Investigating, manipulating materials, and testing hypotheses to determine a result

Source: (Catherine Valentino, 2000)

Table 2.2: Critical Thinking Skills

Critical Thinking Skills	
Skill	**Description**
Analyzing	Studying something to identify constituent elements or relationships among elements
Synthesizing	Using deductive reasoning to pull together key elements
Evaluating	Reviewing and responding critically to materials, procedures, or ideas, and judging them by purposes, standards, or other criteria
Applying	Using ideas, processes, or skills in new situations
Generating Ideas	Expressing thoughts that reveal originality, speculation, imagination, a personal perspective, flexibility in thinking, invention or creativity
Expressing Ideas	Presenting ideas clearly and in logical order while using language that is appropriate for the audience and occasion

Source: (Catherine Valentino, 2000)

Table 2.3: Scientific Reasoning Skills

Scientific Reasoning Skills	
Skill	**Description**
Longing to Know and Understand	The desire to probe, find information, and seek explanation
Questioning of Scientific Assumptions	The tendency to hold open for further verification presented assumptions, encounters, and ideas
Search for Data and Its Meaning	The propensity to collect information and to analyze it in context
Demand for Verification	The inclination to repeat and replicate findings and studies
Respect for Logic	The inclination to move from assumption to testing and data collection to conclusions
Consideration of Premises	The tendency to put into context the reason for a particular point of view
Consideration of Consequences	The tendency to put into perspective the results of a particular point of view
Respect for Historical	The inclination to understand and learn from earlier ideas, studies, and events

Source: (Catherine Valentino, 2000)

Strategies for Change in Science process skills

Recognizing the importance of developing science process skills in elementary and secondary schools, carefully defining and organizing these skills are necessary. A major stumbling block is to focus on teaching science process skills in isolation from their real world applications. A wide body of research suggests that learning to solve problems in a variety of contexts fosters the development of a general problem-solving ability that can be transferred to new contexts (Valentino, 2000). Without practice in applying science skills in real problem-solving situations, transfer is unlikely to happen.

To help teachers create an environment in which students make connections between learning science process skills in school and applying them in daily life, Valentino, (2000) emphasizes the following key teaching strategies:

Motivate: Teachers should look for current events that excite children and adults. An extensive survey completed by Valentino,(2000) within seven years suggests that the following events are winners: discrepant events or science "magic" such as the wind picking up Nicole's coat, danger and disasters, science fiction, world records, and sensational demonstrations such as chemical changes.

Model scientific curiosity: Teachers should bring in newspaper or TV news articles to stimulate discussion. Share them with the students, and tell them what you find exciting or interesting. Teachers should also ask questions aloud and encourage the students to ask their own.

Reinforce scientific thinking: Teachers should make a "Question Collection" and periodically choose a question to initiate a science exploration or activity. Teachers should also publish a student Science Quest Newsletter with answers researched by the class.

Assess science process skills: There's an old educator's saying that says "if you don't assess it, you won't get it." Teachers should help the students' to understand what the different kinds of science process skills are and the important role they will play in their future.

Factors Influencing the Acquisition of Science process skills

Although many factors may account for students' difficulties in science process skills acquisition, some possible factors to be considered include:

1. Teachers' Role

Literature suggestions that there are various factors that influence the acquisition of cognitive skills such as science process skill. The teacher plays an important role in learning, including the acquisition of science process skills. Moranzo, Pickering and Pollock (2001) assert that, although schools make little difference, that is only approximately 10% in students' achievement, the most important factor affecting students' learning is the teacher. According to them, teachers can have a profound influence on students learning even in school that are relatively ineffective. Harlen (2000) identifies three main aspects of the teacher's role:

i. setting up the learning environment;
ii. organizing classroom activities; and
iii. interacting with students.

Among these aspects, the most important aspect is teachers' interaction with students during their teaching. A teacher has to help students in engaging them to think while performing the task given. The teacher should ask the right question in order to engage students' thinking, facilitate them by asking how they would test their ideas, encourage them to further explore and serve as expert when they needed one.

2. Students' Readiness/Motivation

Apart from the teacher's role, readiness is another factor that influences the acquisition of science process skills. Students' readiness is perceived as learner's developmental level of cognitive functioning (Driscoll, 2000). It is the cognitive maturity that is assumed to determine the extent to which learners are capable under consideration in teaching students. Based on Shayer and Adey's (1981) (cited in Saat and Kamariah, 2005) taxonomy, students being at the concrete level of Piagetian Cognitive Development will not be able to handle multiple variables. They will be able to vary more than one variable only when they are at late concrete and formal level. This is due to the fact that concrete thinkers are not cognitively ready to handle multiple variables.

According to Ghassan (2007), motivation to learn is an important factor controlling the success of learning and teachers face problems when their students do not all have the motivation to seek to understand. However, the difficulty of a topic, as perceived by students, will be a major factor in their ability and willingness to learn it.

Students' motivation to learn is important but does not necessarily determine whether they employ a deep or a surface approach: Aspects of students' motivation to learn can be classified as either intrinsic (e.g. wanting to know for its own sake) or extrinsic (e.g. wanting to learn what is on an exam syllabus). There is also a third class, called 'a motivational' learning, which covers the situation where students do things (like attending lecture) without any conscious belief that this will help them learn anything (Vallerand and Bissonnette, 1992).

Resnick (1987) 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. However, Song and Black (1991) indicated that students may need help in recognizing that school-based scientific knowledge is useful in real-world contexts.

White (1988) argued that the issue of long-term and short-term goals is relevant to the learning of science. The students who goes to lectures with a short-term goal of passing examinations often has a specific approach to learning scientific laws and potentially meaningful facts are learned as propositions unrelated to experience. Too often examinations reward the recall of such facts. On the contrary, the students who have a stronger sense of achievement, or who want to learn about science, may attend the lectures with a long-term goal of a deeper understanding and appreciation of science. They may approach it involving advanced learning strategies of reflection and inter-linking of knowledge. With the pace of normal lectures, there is unfortunately little opportunity for this to occur during the lectures. Students' motivations for learning from lectures have important consequence for what they are attending to, how they are processing information, and how they are reacting to the lectures.

Adar (1969) proposed the existence of four motivational traits that are attributable to students' needs (cited in Ghassan, 2007). She introduced the notion of motivational patterns in her students' sample, and accordingly she divided students into four types: the achievers, the curious, the conscientious and the sociable. Students of different motivational patterns have their preferred modes of learning as well.

Kempa and Diaz (1990a) found that a high proportion of the total students'population could be clearly assigned to one of the four motivational patterns. Kempa and Diaz (1990b) went on to suggest that students with the conscientious or achievers type of motivational pattern would exhibit a strong preference for formal modes of teaching.

Students' readiness affects learning. Saat and Kamariah (2005) viewed readiness as a function of previously acquired knowledge. They emphasized that what students already know influence their learning. Readiness in this aspect depends on the learner's cognitive structure. What they already know facilitates subsequent learning. Taking this point into consideration, it is important for teachers to know their students' prior knowledge before proceeding onto other lesson.

3. Language/Communication

Another factor that influences the acquisition of the science process skills is the language used in the Chemistry teaching-learning process. Language plays a vital role in the learning of chemical concepts, laws and principles. Pupils need training and experience in all aspects of science education so that teachers should strive to impart these chemical knowledge and experience by using good and appropriate science terminology. Chemistry as a subject has its own language or terminology and every Chemistry teacher should teach the subject in such a way as to impart the right language, hence a good Chemistry teacher must make out time to study the terminologies involved.

Science consists of a number of concepts which appear difficult to understand and explaining them in a second language creates its own problem. For instance, those who do not subscribe positively to the use of mother-tongue in science teaching find it difficult to reconcile the use of science teaching concepts with mother tongue. Equally important is the deficiency of science (Chemistry) teachers in the use of a appropriate science language (Keyune and Opara, 2000; Saat and Kamariah, 2005). Language difficulties experienced by science students in a cross-cultural educational environment, is as a result of students' problem which includes: inability to express themselves, poor background, and poor comprehension of English, slow cognitive development, weak vocabularies among others.

In USA, Gabel (1992) has noted that difficulties students have with Chemistry may not necessarily be related to the subject matter itself but to the way of study of the vocabulary skills of pupils in secondary schools. He drew inaccessible to pupil at various stages. He also examined the words and phrases which connect parts of a sentence and which give logical coherence to it (development of logical, arguments are impossible without these logical connectives) he found that many words used frequently by science teachers were just not accessible to the pupils.

In Scotland, similar investigations were conducted and extended into higher education. The study by Cassel and Johnstone (1980) has shown that the non- technical words associated with science were a cause of misunderstanding of pupils and students. Words, which were understandable in normal English usage, changed their meaning (sometimes quite subtly) when transferred into, or out of, a science situation. For example, the word “Volatile” was assumed by students to mean “unstable”, “explosive” or “flammable”. Its scientific meaning of “easily vaporized” was unknown. The reason for the confusion was that “volatile”, applied to a person, does imply instability or excitability and this meaning was naturally carried over into the science context with consequent confusion.

4. Inadequate Equipment/Materials

Inadequate equipment/materials for science teaching-learning process are another factor that influences the acquisition of science process skills. One of the goals of education as it is documented in the National Policy is “the acquisition of appropriate skills and development of mental, physical and social abilities and contributing to the development of his society”. This goal will be difficult to achieve in a school system where equipment/materials for “doing science” is inadequate (Ugwu, 2007).

Students learn science with ease if taught through activities in a well-equipped laboratory. These scientific activities are for the purpose of enabling the learner to acquire necessary science process skills such as observing, measuring, recording, manipulating equipment, interpreting data, drawing inferences and so on. The lack of laboratory equipment, apparatus maintenance and repair of equipment and insufficient practical materials are the order of the day in our educational institution. Students hang onto their wrong perceptions because there is no laboratory and equipment with which they can be taught or shown the inconsistencies in their assumption. Some schools will have good equipment but there will be no standard laboratory while others will have laboratory but no standard equipment.

5. The Physical Setting/Learning Environment

The physical setting or learning environment is also another factor that influences the process skills acquisition. The physical setting is the location of a school in the urban area or rural area, which determine to a great extent students' learning difficulties in Chemistry. An ideal environment is a significant factor in promoting learning. This environment includes the physical setting of the classroom.

Saat and Kamariah (2005) based on their observation concluded, that the physical setting of learning environment could have hindered direct interaction between students and teachers especially the latter's explanation on various concepts or issues. In the learning environment, the teacher should schedule class time to allow for both group and individual activities designed to accomplish specific objectives, create an atmosphere that motivate children to participate freely in planning, carrying out and interpreting results of investigations. Teachers can also use questions to assist students in conducting an investigation without telling them what to do or giving away the expected results, and arrange instructional resources in the classroom (or laboratory) to maximize students' interactional resources available in the school and community.

6. Curriculum Content

The science curricula content is another factor that influences students' science process skills acquisition. The advent of revised school syllabus in the 1960s and 1970s in many countries saw a move towards the present of school Chemistry in a logical order, the logical usually being that of the experienced academic Chemistry. Similarly, early chapters in almost all textbooks for first level higher education courses start with topics like atomic theory, line spectra, formulae, equations, balancing ionic equations, calculations and stoichiometry. This is the grammar and syntax' (Jenkins, 1992) of Chemistry but is daunting for the students. Johnstone (2000) has made arguments against this "logical" presentation cogently; the logical order may well not be psychologically accessible to the learner.

Much school Chemistry, taught before 1960, laid great emphasis on descriptive Chemistry, memorization being an important skill to achieve examination success. The sub-microscopic interpretation and symbolic representation were left until later. Today, the descriptive is taught alongside both the micro and representational: the learner cannot cope with all three levels being taught at once, and Gabel (1999) supports this argument. Indeed, today there is a danger that Chemistry depends too much on the representational, with inadequate emphasis on the descriptive.

Chemistry knowledge is learned at three levels: "sub-microscopic, macroscopic and symbolic" and the link between these levels should be explicitly taught (Harrison and Treagust, 2000; Ebenezer, 2001; Ravialo, 2002; Coll and Treagust, 2003). Also, the interactions and distinctions between them are important characteristics of Chemistry learning and necessary of achievement in comprehending chemical concepts. Therefore, if students possess difficulties at one of the levels, it may influence the others. This, determining and overcoming these difficulties should be our primary goal.

Johnstone (1991) indicated that the nature of Chemistry concepts and the way the concepts are represented (microscopic, macroscopic or representational) make Chemistry difficult to learn. The methods by which students learn are potentially in conflict with the nature of science, when, in turn, influences the methods by which teachers have traditionally taught (Johnstone, 1980, cited in Ghassan, 2007)

In order to determine whether students' understanding of Chemistry would increase if the particulate nature of matter (sub-microscopic level) was emphasized, Gabel (1993) conducted a study involving students in an introductory Chemistry course. Introducing extra instruction to the experimental group that required students to link the particulate nature of matter to other levels (microscopic and symbolic levels); Gabel found that the experimental group performed higher in all levels than the control group. It seems that this kind of additional instruction is effective in helping students make connection between the three levels on which Chemistry can both be taught with the students' having understanding.

Sawrey (1990) found that in an introductory Chemistry course, significantly more students were able to solve the problems and numbers that could solve those depicting particles. Bunce et al (1991) interviewed students who had solved problems out loud. This study indicated that students rarely thought about the phenomenon itself but they searched in, their mind until they came upon something that fitted the condition of the problem.

Eshach and Garik (2001) showed how students (at several school age levels) understood little about the particulate nature of matter or about chemical phenomena in their everyday lives. Surprisingly, some of the incorrect explanations that students gave to common phenomena are concepts that they developed after formal school instruction. Bodner (1991) determined how prevalent these ideas of misconceptions were among the graduate students. His findings indicated that non- scientific explanations persist for some students even after they had graduated with a major in Chemistry. He concluded that students have difficulty in applying their knowledge and they do not extend their knowledge into real word.

Reid, (2000) suggested that the Chemistry syllabus to be taught should not be defined by the logic of the subject but the needs of the learner while Johnstone complementary paper (Johnstone 2000) emphasizes that the order and method of presentation must reflect the psychology of the learner. These two fundamental principles would offer a constructive basis for dialogue in re-structuring the ways Chemistry is offered at school and higher education: in simple terms, define the material to be taught by the needs of the learner, and define the order of presentation by the psychology of learning. Most curricula are not defined by the needs of the next stage and are not defined by the needs of those (often the majority) who will not study Chemistry at the next stage (Reid, 2000). Similarly, Chemistry is a logical subject and its inherent logic is a tempting structure on expert not the learner. Application of science concepts and relevant skills to the needs of the learner, enable the students to see the relationship between science and human needs. This may help to facilitate an understanding of concepts and acquisition of relevant process skills in science.

7. Concept Formation

Hornby (2006) defined concept as an idea or a principle that is connected with something abstract. Learning specific concepts is very much at the heart of learning Chemistry. Concepts like bonding, structure, rate of reaction and internal energy apply to all chemical systems (Fensham, 1975).The application of these concepts has implications regarding understanding the whole chemical process, mainly chemical reaction and properties of substances. According to Hurd(1971), the teachers' effectiveness will depend upon how well he has internalized his subject as a science and how well he understands how scientific concepts are formed.

Robinson (2003) has suggested that students must first thoroughly understand a concept or symbol before they can construct or convert it into the meaningful information it represents. Only then will they be able to cope with the quantitative computation by giving a right interpretation or meaning. In another dimension, teachers of Chemistry often do not have sufficient information about their students and this has also been instrumental to the assumption that students come into the Chemistry classroom, with what, Egbule (2000), refer to as a "clean mental slate". In order to teach Chemistry effectively, teachers need to have a clear and comprehensive view of the nature of personal construction. These includes how students construct their own chemical concepts and symbols, how the expressed chemical concepts can be constructively used in class, how to introduce scientific consensus interpretations or meanings to concepts in their classes, how to conduct problem solving or conceptual change modes effectively in their classes.

Research shows that students usually bring in what is called naïve theories as they deal with the phenomena of Chemistry (Taber, 2001; Taber, 2002 and Ghassan, 2007). They arrived at these theories as part of living in the world and making sense of what happens around them. These constructed theories or misconceptions often interfere with the students' ability to learn and understand certain concepts presented in the classroom and this interference occurs regardless of how clearly the Chemistry teacher presents the concepts (Taber, 2001 and Taber, 2002). These cases abound where students pretend to have actually understood the concepts taught. Students' alternative conception or 'misconception' which are considered to largely stem from the way they have been taught, have been labeled as pedagogic learning impediments (Taber, 2001).The failure to represent concepts such as the reactant molecules or lattice structures concerned is a simplification, which encourages students to develop alternative conceptions (Taber and Coll, 2002).

Misconceptions about pH even after extensive teaching have been reported by Brown-Acquaye (1993). His result revealed lack of understanding of the concepts such as pH, concentration indicator behaviour, moles and their respective role in an acid-base titration by students. Toplis (1998) also conducted a research to determine the extent of students' misconception of the concept of acids and alkalis on eight graders students. In this study, it was concluded that students have more problems understanding what an alkali is, over an acid.

Chemistry learning requires much intellectual thought and discernment because the contents are replete with many abstract concepts. Concepts such as dissolution, particulate nature of matter, and chemical bonding are fundamental to learning Chemistry (Barker and Millar, 2000; Eshach and Garik, 2001). Unless these fundamentals are understood, topics including reaction rate, acids and bases, electrochemistry, chemical equilibrium, and solution Chemistry become arduous. Therefore inquiring into students' conceptions of the fundamental concepts in Chemistry has been a research focus of several researches in the last decade (Ayas and Costus, 2002; Calik, Ayas and Coll, 2006).

Real understanding requires not only the grasp of key concepts but also the establishment of meaningful links to bring the concepts into a coherent whole. Ausubel's important work (1968) cited in Ghassan (2007) has laid the basis for understanding how meaningful learning can occur in terms of the importance of being able to link new knowledge on to the network of concepts, which already exist in the learners' mind. Concepts develop as new ideas are linked together and the learner does not always correctly make such links, this may well lead to misconceptions.

Conceptions or pieces of intellectual thought either reinforce each other or act as barrier for further learning. To overcome obstacles in learning, student conception researchers has been focusing on identifying and assessing students'"misconceptions" (Helm, 1980), "alternative frame work" (Driver, 1981) "children's" science (Gilbert, Osborne and Fenshan, 1982) or pre-conception (Novak, 1977). These labels are attached when students" conception are different from the scientific ideas and explanation (Taber, 2000; Nicoll, 2001; Ayas, Kose and Tas , 2002).

There have been an enormous number of studies on misconception in Chemistry and there are several review of this area (Nicoll, 2001, Coll and Taylor, 2002; Calik, Ayas and Ebenezer, 2005). In addition, various studies indicates that students' difficulties in learning science concepts may be due to the teachers' lack of knowledge regarding students prior understanding of concepts (Lanka, 2007, Farsakoğlu et al, 2008). Bodner (1986) makes a salutary point when he notes that "We can teach – and teach well – without having the students learn."

Chemical knowledge structures, for example , in "combustion""physical and chemical change" and "dissolving solution" by their very nature lead to alternative conception argues Griffiths (1994). Students' conceptions are constrained both by the perceiver (learner) and the perceived (chemical phenomena) (Ebenezer, 1991). This learning involves knowledge that needs to be restructured, adapted, rejected, and even discarded (Duschl and Osborne, 2002. Various other studies have focused on students' concept and their inter–connections. Fensham and George (1973) investigated problems arising from the learning of organic Chemistry while Kelleth and Johnstone (1974) indicated that students had little conceptual understanding of functional groups and their role. This caused difficulties with, for example, esterification, condensation, and hydrolysis. Kempa and Nicholls (1983) found that problem–solving ability above the algorithm level, depends on the strength of the concept interlinking in a students' mind. They also found that a student's ability was dependent on context, such that individual students can do well in the same areas and badly in others.

Empirical Studies on Science process skills acquisition

A review of the literature reveals that science process skills can be developed by engaging learners in authentic learning activities (Keys and Bryan 2001). These are activities that should provide learners with design investigations for solving these problems. This requires teachers to adopt inquiry-based approaches to science teaching and learning. It has been observed from studies carried out by Smolleck et al (2006) and Lanka (2007) that school laboratory experiences introduce important aspects of science to students while simultaneously assisting them in developing knowledge in regard to specific science concepts. Thus, science teachers should have the necessary knowledge and skills for planning and executing learning experiences that will expose learners to inquiry experience, thereby allowing them to apply both cognitive and manipulative processes in solving scientific problems.

From the preliminary study conducted by Lanka (2007) with 17 physics teachers from four senior secondary schools, he found out that:

i. learners should be engaged to design their own investigation and explore various methods of conducting a particular scientific investigation;

ii. learners should be engaged in investigative activities for which the outcome is not apparently obvious to them; and

iii. large classes cannot be effectively used to facilitate investigative/ inquiry activities, they are impracticable.

In the study on cognitive styles as a variable in process skills development in science, Adeyemi (1990) working with 258 class iv students, classified the students into field-dependent, intermediate and field- independent groups using the Group Embedded Figure Test (GEFT). Using two instructional mode- guided inquiry mode and conventional expository, mode, she probed the development of scientific process skills in the subjects. Her findings revealed the following:

i. There was instructional mode main effect on biology process skill achievement in favour of the guided inquiry mode of instruction.

ii. There was no sex main effect on biology process skills achievement.

iii. There was cognitive style main effect on biology process skills achievement, the outcome being greatest for field- dependent group and least for field independent group.

The study carried out by Akinbobola and Afolabi (2010) analyzes the science process skills in West African senior secondary school certificate physics practical examinations in Nigeria for a period of 10 years (1998-2007). Ex-post facto design was adopted for the study. The 5 prominent science process skills identified out of the 15 used in the study are: manipulating (17%), calculating (14%), recording (14%), observing (12%) and communicating (11%). The results also show high percentage rate of basic (lower order) science process skills (63%) as compared to the integrated (higher order) science process skills (37%). The results also indicate that the number of basic process skills is significantly higher than the integrated process skills in the West African senior secondary school certificate physics practical examinations in Nigeria.

Adeyemi (1991) worked on the development and implication of an instruction for the assessment of performance in biology process skills task (a challenge for Nigerian science teachers) used 42 students for guided-inquiry and 47 students in the conventional expository mode (SS2 students) of the total subjects 53 were boys and 36 girls. Pretest was given on process skill and posttest was also given after the treatment. Her results showed that the F-values for the process skills observation, manipulation, formulating hypotheses interpretation of data, inference/reasoning and self-reliance were all significant at $P < 0.05$ and this was in favour of the guided-inquiry instructional group. Also the overall performance on all the process skills by the guided- inquiry group was higher than that of expository group. She also found that the difference posttest mean score on skills like counting, measurement, communication, classification, experiencing, orderliness and work habit were statistically significant.

Onwuneme (1992) researched on students' experienced difficulty in process skill acquisition in Edo and Delta State using the senior secondary school biology curriculum. She worked with 600 SS3 students and her findings showed that there are 8 areas of difficulty in process skill. These are counting/number relations, communication, prediction, inference, controlling and manipulating variables, experimenting, manipulative techniques (instrument) and building mental models. Moreover it was found that building mental models was the process skill found most difficult (2.9111, $S = 0.8854$, $Z = 9.721$). This was followed by manipulative techniques, controlling and manipulating variables, communication, experimenting counting and number relations, prediction and inference. The results indicated that students in general found the following process skills most difficult: observation, formulating hypothesis, making operational definitions, measurement, interpreting data and classification, the last one being found simplest.

Nwosu and Okeke (1995) who researched on the effect of teacher sensitization of students' acquisition of science process skills found out that the significant increase in the level of acquisition; both for the aggregate and individual skills; among SS1 students due to the treatment indicates that sensitization increased the effectiveness of the teacher to bring about process skill acquisition. The results also indicated that the relative gain due to treatment is more than the basic skills. Thus treatment enhanced the level of acquisition of process skills both quantitatively and qualitatively. The acquisition of the higher skill is highly valued since these skills distinguish the scientists from the technologist and form the basis for problem solving.

In a study of the levels of acquisition of science process skills among class one senior secondary school students, Nwosu (1994) worked with 502 SS1 students. The findings of this indicate a low level of acquisition of science process skills among SS1 biology students. The scores for the individual skills ranged from 26.08% for the skill of interpreting data to 43.94% for the process skills ranged from 26.08% for the skills interpreting data to 43.94% for the process skill of measuring. The mean score for the aggregate skills was found to be 34.58%. Apart from the skills of measuring, observing and predicting where the pupils scored pass marks, the pupils could not score pass marks on the other skills. This poor performance is not encouraging, especially when one consider that these SS1 pupils have been exposed in the primary and junior secondary school to 9 years of science curricular all advocating the acquisition of science process skills plus the few weeks exposure to the first unit of SS1 biology curriculum which specified the acquisition of the a process skills investigated as the performance objective. These students are therefore expected to acquire the science poor performance in the level of acquisition of science process skill among top primary science curriculum, the junior secondary school integrated science and the WAEC syllabus scored the highest mark of 31.08% for the process skill observing while the lowest score of 6.69% was obtained for the skill of predicting. The study showed that despite all the curricular innovations especially in the senior secondary schools, advocating more strongly than before the acquisition of science process skills as their major objectives, our students are not yet acquiring these skills to the expected level. This constitutes an educational problem that should be attended to urgently.

Akpokorie (2000) also researched on students' experienced difficulty in 15 process skills acquisition on Integrated Science using 600 JSS3 students from Delta State and his findings showed that:

There are 8 areas of difficulty out of the 15 process skills: these are counting/ number relations, communication, prediction, inference, controlling and manipulating variables, experimenting, manipulative techniques (instrument) and building mental models. Moreover, it was found that building mental models was the process skills found most difficult ($x = 2.94$, $S = 0.89$, $Z = 11.99$). This was followed by manipulative techniques, controlling and manipulating variables, communication, experimenting, counting/number relations, prediction and inference. The results indicated that students in general found the following process skills not difficult: observation, formulating hypothesis, making operational definitions, measurement, interpreting data and classification, the last one being the simplest. Majority of integrated science students found 6 areas of process skills to be difficult: these are building mental models, controlling and manipulating variables, manipulative techniques, counting/number relations, experimenting and communication; building mental models being found difficult by the largest proportion of students ($P = 0.735 = 73.5\%$, $Z = 11.520$) while others follow in their order of unpopularity. The remaining areas of difficulty namely, prediction and formulating hypothesis were not found difficult by a significant majority of students.

Ugwu (2007) carried out a study to find out teachers' difficulties in inculcating practical skills in students by using 38 Chemistry teachers in the six education zones in Enugu State. The result of this finding indicates that a lot of factors contribute towards teacher's inability to inculcate practical skills in students. Two of these factors- poor funding of schools/ laboratories by the government and deficient assessment instrument in use have the highest mean score of 2.90. These need serious and urgent attention as much cannot be achieved by our much desired science and technology without the acquisition of science process skills. The researcher used assessment instrument in external examinations that a really measured the process skills acquired to a reasonable level of accuracy.

Nwosu (2002) also carried out a study to investigate the level of acquisition of inquiry skills by senior secondary school girls using 8 science process skills. 245 SS1 girls in six intact science classes were used for the study. Two different researchers produced tests a cognitive ability test (to determine homogeneity and ability groups) and the Test of Acquisition of science process skill (to determine types and levels of acquisition of skill), were administered to the students. The findings of this study indicate a low level of acquisition of the inquiry skills among the secondary school girls especially those in low ability group girls, could only score about 40-56% in the lower order or basic skills (observing, measuring and classifying) but scored below pass grade (40%) in higher order skills like inferring, predicting, hypothesizing, experimenting and interpreting.

More recent work was also carried by Mei, Kaling, Xinyi, Sing and Kboon (2007) to investigate how science process skills can be promoted and the relevance of science through science ALIVE! Programme. 147 students from four secondary 2 Express classes attended the science ALIVE! Programme and participated in the study. Four classes secondary 2 Express Students attended one of four modules in the science ALIVE! Programme and responded to a pre-and post-course survey to measure their perceived skill competency for each process skill. In the pre and post-course surveys, students were asked to rate their perception of their science process skills using a four- point Likert scale. In the pre-course survey, the items which scored less than 3 are the skills of planning investigations, analyzing data, “writing scientific reports and learning by asking question. Students’ perception rating increased in the following skills “using scientific apparatus”, “analyzing data” and learning by asking questions’ with the exception of “planning investigations” and “writing scientific reports” where there was marginal increase or no change between the pre-and post- course rating. The data was triangular with teachers’ feedback, which was used to provide insight of the factors that affect the acquisition of the process skills. The findings show significant increase in students’ perception of skill competency in the various science process skills and more awareness of the relevance of science in their lives.

Another current research was the study carried out by Bozdogan, Tasdemir and Demirbas (2006) on the effect of cooperative learning method in science education on improving the students’ science process skills. Two schools were used to collect data that formed the investigation. Cooperative learning (Jigsaw and Group Investigation Methods) was implemented in the two classes and, an evaluation was made to determine whether achievement in science process skills improved or not. The result of the study revealed that:

i. In both the Jigsaw and the Group Investigation methods of cooperative learning, more learners achieved the skill of graphing in the post- test compared to the pre- test;
ii. In both the Jigsaw and the Group Investigation methods of cooperative learning, more learners achieved the skill of experimenting in the post- test compared to the pre- test;
iii. More students achieved the skill of observation in the pre- test as compared to the post- test after exposure to the Jigsaw and the Group Investigation. The subjects exposed to the Group Investigation method achieved the same before and after exposure to the cooperative learning method; and
iv. More learners achieved the skill of controlling variable in the post-test as compared to the pre-test after exposure to the Group Investigation method of cooperative learning.

More also, another more recent research was by Farsakoğlu et al (2008) who carried out an analysis on the awareness levels of prospective science teachers on science process skills using a qualitative and quantitative analysis. The study was carried out in the form of a case study with 40 senior prospective science teachers (PST) in the academic year of 2007-2008. A science process skills questionnaire and a science process skills test consisting of 12 process skills were prepared and applied to the senior PST. According to the data obtained from the questionnaire and test results, the PST who could explain science process theoretically had difficulty when transferring the theoretical knowledge into practice. From the data obtained from the science process skills test, “collecting data and preparing data table” (15.75% PST), “drawing graph” (26.88% PST) and “identifying variables and forming hypotheses” (open- ended questions 9.38% PST) had lower true answering percentage on “identify variables and formulating hypotheses” (multiple choice questions 73% PST)), controlling variables and designing an experiment (91.25% PST) and interpreting the data and reading the graph (85.75% PST). The results of the study also revealed that learning environment, personal attributes, phenomena, scientists’ lives models and activities, technology, daily life, experiments and documentary film and experience are important factors for the development of science skills.

Gender Related Differences and Science process skills

Ukwungwu and Ezike (2000) have noted that many factors have been known to affect the academic performance of students in science and Chemistry in particular. Among these factors is the difference between boys and girls or gender.

Nnaka (2008) carried out a study on the level of responsiveness of science teachers’ gender related issues in the teaching of science subjects. A total of 120 science teachers randomly sampled from Awka education Zone made up the sample. Finding based on the analysis of data led to the following conclusions:

i. Science teachers responded negatively to gender issues in the classroom
ii. Science teachers have very low expectation of girls in science classes
iii. Science teachers still assign roles to students based on gender

iv. Girls do not get encouragement from science teachers in the class

Akpokorie (2000) also researched on the effects of sex on difficulties experienced by students in 15 process skills using 600 JSS3 integrated science students from schools in Delta State and the study revealed that; sex has no significant effect on the magnitude of difficulties experience by integrated science students on each of the 15 process skills.

More also, Ugwu (2007) carried out a study to find out the influence of gender on the difficulties encountered by teachers in Chemistry practical using 38 Chemistry teachers (22 females and 19 males) in the six education zones in Enugu State. The study revealed that gender is not a significant factor on the difficulties encountered by Chemistry teachers in practical work.

Opara (2008) also carried out a study designed to investigate the efficacy of self-regulation in facilitating curriculum delivery and students' achievement in Chemistry using 284 SS3 Chemistry students (142 males and 142 females) from four single-sexed secondary schools in Orlu Education Zone of Imo State. The study also revealed that gender had no significant difference in achievement in between male and female in the experimental groups. Hence, to maximize students' achievement in Chemistry classroom lessons should be activity- orientated and should encourage students to engage in in-depth thinking. Opara's findings therefore revealed that gender did not have significant impact on students' achievement in Chemistry.

After an analytical review of research studies on sex differences, Mordi (1992) further concluded that scientific studies support the following opinions held about how males and females differ.

Boys show higher achievement in science than girls.

Boys are more interested in science and tend to have positive attitude towards science.

More also, other studies by Eziefe (1990); Osakwe (1991); Umueodoagu (1995);

Shaibu and Mari (1997) show that girls tend to shy away from physical science subjects, like Chemistry. These have mostly returned the verdict of male superiority. But, Adebola (2004) in his study found that while there is no significant gender difference in students' performance in JSS mathematics, their performance in SSS mathematics is significant in favour of the boys.

School Location Related Differences and Science process skills acquisition

Also playing an important role in students' performance in science and acquisition of process skills is school location. School location in this study refers to the setting of schools (either urban or rural).The location of a school can influence a student's acquisition of science process skill (Inomiesia, 1989; Adedayo, 1997; Akpochafo, 2001; Agbogoroma, 2009 and Omajuwa, 2011) as well as general knowledge in science.

Studies carried out by Adedayo (1997) and Akpochafo (2001) showed that students from urban centre had higher scores on Raven standard progressive matrices than rural students and that the environment influences a student's intellectual development in school. Abdullahi, (1982) constructed a standard test in urban and rural areas. He sampled 726 students from both urban and rural areas and determined that students from urban schools out performed students from rural schools.

Adeyemi, (1990) carried out an empirical study on the effect of school setting on students' attitude to biology. Although part of her study supported urban over rural dominance in attitude formation, the posttest score favour the urban subjects in terms of attitudes towards biology. Agbogoroma, (2009), examined the effect of school setting on students' knowledge of integrated science using a sample of 360 JSIII students drawn from six secondary schools located in urban rural settings. Both studies reported that the urban students significantly performed better than the rural students' in the acquisition of knowledge of integrated science.

Okoye, (2009) investigated on the effect of gender and school location on students' performance in Nigerian Integrated Science. The subject for the study were six hundred junior secondary school three (J.S.S III) students randomly selected from eight secondary schools in Okpe, Warri South and Uvwie Local Government areas of Delta State, Nigeria. From the result, there was a significant difference between the performance of male students from urban secondary schools and female students from rural secondary schools. Thus, male students from urban secondary schools performed significantly better in integrated science than female students from rural secondary schools.

But, contrary to this, the study of Omajuwa, (2011) using a sample of 360 SS11 students, drawn from 18 schools in Delta North Senatorial district, showed that, school location has no significant effect on the difficulties experienced by Chemistry students on process skills acquisition.

School Type Related Differences and Science process skills acquisition

Also playing an important role in students' performance in science and acquisition of process skills is school type. School type in this study refers to single sex schools and coeducational or mixed schools. The type of a school can influence a student's acquisition of science process skill.

One strategy that has been the subject of recent attention is single-sex schooling. Advocates of single-sex schooling have claimed that current coeducational schooling disadvantages boys, and teaching boys and girls separately will boost boys' achievement and reduce the gender gap. For example, Sax (2005; 2007) argues that boys and girls have a number of 'hardwired' differences that are best accommodated by single-sex schooling. He claims that 'in the coeducational classroom so many of the choices we make are to the advantage of girls, but disadvantage boys' (Sax, 2008) and that schooling boys and girls separately is the best way to accommodate boys' needs without disadvantaging girls. These claims regarding the benefits of single-sex schooling for boys are in contrast to claims made in the 1980s and 1990s that single-sex schooling is advantageous for girls, particularly in mathematics and science (Carpenter and Hayden, 1987).

A number of studies have examined the effects of single-sex schooling on educational achievement for males and females. In many cases, the results of these studies have suggested that the effects of single-sex schooling may vary with gender. For example, Malacova (2007) examined the effects of attending a single-sex school on progress in GCSE in a sample of British high school students. Malacova's study reported that, after controlling for prior attainment, both girls and boys benefited from single-sex schooling, and there was some suggestion that girls benefited slightly more than boys. Lee and Bryk (1986) examined educational achievement gains during attendance at single-sex and coeducational Australian Catholic high schools, as measured by test score gains on the reading, mathematics, science and writing components of the High School and beyond test battery. This study found that pupils in single-sex schools had higher levels of achievement than pupils in coeducational schools, and that the advantages for single-sex schooling tended to be greater for girls than for boys. Lee and Bryk's study has been criticized for failing to adequately control for pre-existing differences in achievement, behaviours and attitudes that may account for the school-type effects (Marsh, 1989), although these criticisms apply more to the raw performance outcomes and somewhat less to the gain scores reported above.

Van de Gaer et al. (2004) examined achievement in language and mathematics for a sample of Belgian high school pupils. Van de Gaer et al. found that, after due allowance was made for selection factors, single-sex schooling had no significant effect on boys' achievement but, for girls, it had a significant positive effect on mathematics achievement. Lee and Marks (1990) examined the effects of single-sex schooling on SAT scores for US high school students. While single-sex schooling did not have a significant effect on either mathematics or verbal SAT scores for males or females, there was some suggestion that the effects of single-sex schooling were different for males and females. Specifically, for males, mathematics SAT scores were higher amongst those attending single-sex schools while, for females, mathematics SAT scores were higher for those attending coeducational schools. For verbal SAT scores the pattern was somewhat different, with males having similar scores at single-sex and coeducational schools, and females having higher scores at single-sex schools. Other studies have found that the effects of single-sex schooling are the same for males and females. Young and Fraser (1992) found that gender differences in science achievement in Australian high school students were similar at single-sex and mixed schools.

In order to provide more conclusive support for the view that single-sex schooling reduces the gender gap in educational achievement, it is necessary to directly compare the size of the gender gap at single-sex and coeducational schools, or to directly compare the effects of single-sex schooling for males and females. Very few studies have performed these direct comparisons. One is a study by Marsh (1989), who re-analyzed Lee and Bryk's (1986) data on educational achievement gains during attendance at single-sex and coeducational Australian Catholic high schools. In addition to the analyses originally reported by Lee and Bryk, Marsh also reported the results of a test of the interaction between gender and school type. Marsh found that, after controlling for background factors and prior achievement, there was no significant difference in the size of the gender gap at single-sex and coeducational schools for reading, mathematics, science or writing. Marsh's results, therefore, do not provide support for the view that single-sex education moderates the gender gap in educational achievement from the study carried out. Marsh's study has been criticized by Lee and Bryk (1989) for over-controlling for covariates. Specifically, Marsh has been criticized for controlling for performance in sophomore year, by which time school-type effects may have already been established. Similar results were reportedly found by LePore and Warren (1997), who found no significant differences in the size of the gender gap at single-sex and coeducational schools for 10th- and 12th-grade achievement in reading, mathematics, science or history in Australian Catholic high school students, although LePore and Warren did not report the results of the statistical tests that they performed.

Lauritzen, (2004) in his study, reviewed the current literature pertaining to the effect of single-sex schooling on academic achievement. Drawn from the United States, England, Canada, Australia, Nigeria, Thailand, Ireland, and Jamaica the literature review contains studies that both support and oppose the hypothesis that single-sex schools confer some form of academic advantage upon their students. There is no evidence that conclusively determines when or if school type alone has an impact on the academic achievement of students. This issue is made more complex when the studies control for outside factors like prior achievement, selective admissions policies, class size, and private versus public schools. The literature shows no consistent pattern of effect that supports the superiority of either single-sex or coeducational school type as a single variable, with specific regards to academic achievement.

Another study (Wong et al., 2002) examined achievement in high school leaving examinations in English, Chinese and mathematics in a sample of Hong Kong high school students. Wong et al. found that the effects of single-sex schooling were different for boys and girls. Specifically, boys performed better at coeducational schools, while girls performed better at single-sex schools. This pattern was consistent across the three subject areas. While Wong et al.'s results do support the view that the effects of single-sex schooling vary according to gender, they do not support the view that single-sex schooling reduces gender differences in educational achievement; instead, the results suggest gender differences in educational achievement will be smaller at coeducational schools. Another study by Marsh et al. (1988) took a different approach and examined educational achievement in English and mathematics in students attending a high school that changed from single-sex to coeducational. The results of Marsh et al.'s study indicated that there were no significant changes in the size of the gender gap after the change to coeducation.

Also, the study by Woodward, Fergusson, and Horwood,(2010), examined the effects of single-sex and coeducational schooling on the gender gap in educational achievement of 1265 students. After adjustment for a series of covariates related to school choice, there were significant differences between single-sex and coeducational schools in the size and direction of the gender gap. At coeducational schools, there was a statistically significant gap favouring females, while at single-sex schools there was a non-significant gap favouring males. These results indicate that single-sex schooling may mitigate male disadvantages in educational achievement.

The study of Omajuwa (2011) using a sample of 360 SS11 students, drawn from 18 schools in Delta North Senatorial district, showed that, school type has no significant effect on the difficulties experienced by Chemistry students on process skills acquisition.

Class Size Related Differences and Science process skills acquisition

Class-size is an educational tool that can be used to describe the average number of students per class in a school. Hoffman (1980) described it as the number of students per teacher in a class. Kedney (1989) saw it as a tool that can be used to measure the performance of the education system. In relation to size, Stepaniuk (1969) reported that the rational utilization of classroom space depends upon class-size. This in turn would depend upon the area of the classroom. He argued that there are approved norms of class-size, 40 pupils per class for grades 1 to 8 and 35 pupils per class for the senior classes; while the standard allocation of class space per pupil is 1:25 square metres. In this regard, Dean (1994) compared class-size in some countries and found that Turkey, Norway and Netherlands had class-sizes of 20 or more; the UK, USA, Japan, Canada and Ireland had class-sizes of between 15 and 20 while France, Sweden, Denmark, Austria, Italy, Luxembourg and Belgium had class-sizes of below 15.

In Nigeria, however, Okoro (1985) reported that the class-size in secondary schools ranges between, 35 to 40 students. He argued that few pupils per class are uneconomical, as they do not make full use of space, teachers and teaching materials. Commeyras (2003) however, disagreed with these arguments and reported that effective teaching seems impracticable for teacher educators having large class sizes of 50, 75, 100 or more.

Class size is also perceived as relevant to student (Brophy 2004). It is important to know the major problems in teaching and learning and to transfer skills and knowledge from generation to generation. A number of factors could affect teaching learning activities. Some of these factors are external, while others are internal to the classroom situation. Among the internal factors to the classroom situation are: problems of classroom management; problems of large class size.

The question, “Are smaller classes better than larger classes” continues to be debated among teachers, administrators and parents as well as in the research community. However, Robinson (1990) concluded that research does not support the expectation that classes will of themselves result in greater academic gains for students. He observed that the effects of class size on student learning vary by grade level, pupil characteristics, subject areas, teaching methods and other learning interventions. Adeyela (2000), found that large class size is un-conducive for serious academic work. Also Afolabi (2002) found no significant relationship among the class size and students’ learning outcomes.

The terms “large” and “small” are obviously a matter of debate. In some published studies, “small” is defined as “30 or fewer students” while “large” is defined as “70 or more students” (Gibbs et al., 1996; Toth and Montagna, 2002). Other studies distinguish “normal” classes as consisting averaging 39 students and “mega classes” of 120 or more students (Hancock, 1996). Other papers define a “small” class as having a ceiling of 55 students and a “large” class as having a ceiling of 120 students (Maxwell and Lopus, 1995). Averaging these different views we arrive at the following definitions. A “small” class has around 41 students;

a “large” class has around 103 students. Very large classes (or “mega-classes”) have at least 103 students with no ceiling.

Class Sizes	**Number of Students**
A. Small	<35
B. Small-Medium	36-50
C. Moderately large	50-70
D. Large	70-110
E. Very Large	110+

According to Ajaja (2010) very large class sizes, which exist in schools, have made healthy interactions between students and teachers almost non-existent. Most teachers hardly know their students by their names. The large class size has reduced individual student’s attention during practical lesson. Students seeking special attention as a result of lack of clear instruction in practical lessons are hardly attended to. All these culminate in very poor performances of students in test of practical knowledge in final year examinations.

A number of studies have looked at the influence of class size on a variety of teaching and learning issues. Class size was also identified by most respondents as a major hindrance for effective teaching and learning. Chemistry requires getting the students involved, as most of the topics involve demonstration, if they could be well understood but this becomes very difficult when the class is large. This is also consistent with Onocha (1985) who found out that large class size is un-conducive for serious academic work.

Adeyemi (2008) examined the influence of class-size on the quality of output in secondary schools in Ekiti State, Nigeria. The population of the study comprised all the 141 secondary schools that presented students for the year 2003 SSC examinations in the State. A sample of 120 schools was selected through stratified random sampling technique. Data were collected through an inventory and were analysed with the use of chi square test, correlation analysis and t- test. Semi-structured interview was conducted with selected principals and education officers. Their responses were analysed through the content analysis technique. The findings revealed that schools having an average class-size of 35 and below obtained better results in the Senior Secondary Certificate (SSC) examinations than schools having more than 35 students per class. The mean scores were higher in schools having an average class-size of 35 and below. The interviewees' responses supported the findings as they supported small class-sizes in schools.

Laboratory Adequacy Related Differences and Science process skills acquisition

Laboratory has been described as a room or a building specially built for teaching by demonstration of theoretical phenomenon into practical terms. With the laboratory experience, students will be able to translate what they have read in their texts to practical realities, thereby enhancing their understanding of the learnt concepts. Farombi (1998) argued the saying that seeing is believing is the effect of using laboratories in the teaching and learning of science and other science related disciplines as students tend to understand and recall what they see more than what they hear. Laboratory is very important and essential to the teaching of science and success of any science course is much dependent on the laboratory provision made for it.

Lending credence to this statement, Ogunniyi (1982) said that there is a general consensus among science educators that laboratory occupies a central position in science instruction. It could be conceptualized as a place, where theoretical work is practicalized and practical in any learning experiences involve students in activities such as observing, counting, measuring, experimenting, recording and carrying out fieldwork. These activities could not be easily carried out, where the laboratory is not well equipped. There is usually a strong move to emphasize the dependence of Chemistry teaching on the existence of a well-equipped chemistry laboratory. In this study, Bajah (1980) found that the correlation between the laboratory adequacy and Science process skills acquisition is significant. Ango and Silo (1986) asserted that laboratory work among others:

i. stimulate learners' interests as they are made to personally engage in useful classroom activities;
ii. affords the learner the basic skills and scientific method of solving problems; and
iii. promotes long term memory of the knowledge obtained.

Laboratories play a significant role in effective Chemistry education. Laboratory classes are supplementary to Chemistry education and make up a crucial part of Chemistry courses. Laboratories are very important to comprehend abstract Chemistry concepts (Demirtaş in Burak 2009). Şahin-Pekmez in Burak, 2009 inquired why science teachers felt they need to carry out experiments in their classes. Teachers' responses included:

i. helping students understand and learn better;
ii. enhancing their interest in classes;
iii. improving their manual skills;
iv. helping them discover knowledge on their own;
v. improving their observation skills;
vi. enhancing their problem-solving skills; and
vii. ensuring students learn through experience.

Chemistry is a subject that involves a lot of demonstrations and can only be effectively taught in the laboratory for easy access to instructional materials; however, most schools lack essential facility. Hofstein and Naaman (2007) reviewed and reported several studies conducted in various countries about laboratory applications. In their evaluation, they stated that laboratory applications aimed to enhance students' science process and problem-solving skills and their interest in and attitudes toward scientific approaches in accordance with the objectives of basic science education. In order to construct knowledge on their own and to acquire problem-solving skills, students need to study in a laboratory environment that brings science process skills in prominence. Science process skills form the basis of the ability to conduct scientific research. These skills constitute a general definition of the logical and rational thought that an individual uses throughout his/her lifetime (Aydoğdu and Kesercioğlu in Burak 2009).

Studies aiming to equip students with science process skills have concluded that students acquire each science process skill through certain stages (Saat, 2004). These stages have been identified as recognition of scientific process, making habits, and automation. At the stage of recognition, a student recognizes the skill and related terms either in lower-grade Chemistry classes or in the learning environment developed by the researcher. At the second stage, the student is familiarized with the process skills and can provide different examples related to these skills, but cannot use them in different areas as she/he is experiencing a mental confusion. At the third stage, she/he can easily define the terms related to the skills and can apply them to other situations. Laboratories should be used efficiently and classes should employ student-active learning processes for students to go through these stages easily (Aydoğdu and Kesercioğlu, 2005 in Burak 2009).

An effective laboratory environment requires the following conditions: teachers should be prepared and planned for classes and have previous experience for the experiment to be carried out in the class; students should have conceptual pre-knowledge about the experiment; students should be provided an environment to use and reinforce such knowledge; basic and higher-level science process skills should be used; links should be established between the subjects taught in classroom and laboratory and their daily lives; and the laboratory environment should introduce innovations. Furthermore, laboratory safety should be effectively maintained and safety awareness should be raised among students.

To equip students with science process skills in classroom environment, laboratories should be efficiently used by teachers and students and teachers themselves should possess these skills. Nevertheless, in numerous studies conducted with university students and prospective teachers demonstrated that they have insufficient science process skills. A teacher who is not properly equipped with these skills may experience difficulty to deliver these skills to his/her students (Lavrenz, 1975). It is observed that the teachers not possessing science process skills and cannot use laboratories efficiently and avoid performing experimental activities, thus Chemistry courses are mainly presented theoretically (Şahin-Pekmez in Burak, 2009).

Lack of Chemistry labs in some schools; sharing physics, Chemistry, and biology labs; unsafe labs due to the use of hazardous substances in experiments (Yılmaz in Burak, 2009); overcrowded classrooms (Johnstone, 1989); lack of time and materials; equipment costs (Millar, 2004); and insufficient laboratory applications in Chemistry classes at schools due to the inability of teachers to use labs effectively and their negative attitudes toward laboratory applications (Burak, 2009) all demonstrate the inefficient use of laboratories (Çepni, Şan, Gökdere and Küçük, cited in Burak, 2009).

The study of Burak, (2009) aims at investigating whether science process skills and efficient laboratory use are significantly correlated with the university students' basic Chemistry course achievement. The Questionnaire for Student Opinions on their Scientific Process Skills was used to determine the extent to which science process skills that were taught in laboratory applications from the students' perspective. The Efficient Laboratory Attitude Scale was employed to assess whether they used laboratories effectively. And the students' course achievement scores were measured by using the Science Achievement Test. The sample consisted of 180 university students who took the general Chemistry course at a state university in the second semester of the academic year 2006–2007. A positively significant and linear relationship was found between science process skills taught in laboratory applications and efficient laboratory use of the students; between their efficient laboratory use and between their science process skills.

Students' Attitude Related Differences and Science process skills acquisition

The word attitude (from Latin apt us) is defined within the framework of social psychology as a subjective or mental preparation for action. It defines outward and visible postures and human beliefs. Attitudes determine what each individual will see, hear, think and do. They are rooted in experience and do not become automatic routine conduct.

Attitude means the individual's prevailing tendency to respond favourably or unfavourably to an object(person or group of people, institutions or events). Attitudes can be positive (values) or negative (prejudice). Social psychologists distinguish and study three components of the responses: (a) cognitive component which is the knowledge about an attitude object, whether accurate or not; (b) affective component: feelings towards the object and (c) conative or behavioural component, which is the action taken towards the object**.**

Attitude as a concept is concerned with an individual way of thinking, acting and behaving. It has very serious implications for the learner, the teacher, the immediate social group with which the individual learner relates and the entire school system. Attitudes are formed as a result of some kind of learning experiences. They may also be learned simply by following the example or opinion of parent, teacher or friend. This is mimicry or imitation, which also has a part to play in the teaching and learning situation. In this respect, the learner draws from his teachers' disposition to form his own attitude, which may likely affect his learning outcomes.

In his observational theory, Bandura (1971) demonstrated that behaviours are acquired by watching another (the model, teacher, parent, mentor, and friend) that performs the behaviour. The model displays it and the learner observes and tries to imitate it. Teachers are, invariably, role models whose behaviours are easily copied by students. What teachers like or dislike, appreciate and how they feel about their learning or studies could have a significant effect on their students. Unfortunately, however, many teachers seldom realize that how they teach, how they behave and how they interact with students can be more paramount than what they teach. In a nutshell, teachers' attitudes directly affect students' attitudes. Teachers' attitudes are in turn, influenced by their culture and belief system.

Teachers' attitudes towards their students in school must be favourable enough to carry students along. Papanastasiou (2001) reported that those who have positive attitude toward science tend to perform either in the subject. The affective behaviours on the classroom and strongly related to achievement, and science attitudes are learned (George and Kaplan, 1998), the teachers play a significant role during the learning process and they can directly or indirectly influence the student's attitudes toward science which in consequence can influence students' achievement. Teachers are, invariably, role models whose behaviours are easily mimicked by students. What teachers like or dislike, appreciate and how they feel about their learning or studies could have a significant effect on their students. By extension, how teachers teach, how they behave and how they interact with students can be more paramount than what they teach.

When the learner exhibits the expected behaviour or response, the value attached determines very significantly the effectiveness of the learning processes in any aspect of education. Gangoli cited in Igwe (2002) stipulates that for teaching and learning of science to be interesting and stimulating, there has to be motivation on the part of both the teacher and the learner so as to ensure the development of positive attitude and subsequently maximum academic achievement. It has been observed that teachers teach science in a way that merely requires the pupils to listen, read and regurgitate. This depicts negative attitude to teaching. Several research findings have confirmed the hypothesis that teachers' attitude either towards science or towards science teaching affect their students' achievement in and attitudes towards science. Okpala, (1985) found that the effect of teachers' attitude towards assessment practices on students' achievement and their attitude towards Physics was positive. In the same vein Onocha, (1985) reported in one of his findings that teachers' attitude towards science is a significant predictor of pupils' science achievement as well as their attitude. Also Igwe (1985) showed that the effect of teachers' attitudes to mathematics was stronger on the students' mathematical achievement than on their attitudes.

Attitude could be defined as a consistent tendency to react in a particular way-often positively or negatively–toward any matter. Attitude possesses both cognitive and emotional components. Fazio and Roskes (1994), said, "attitudes are important to educational psychology because they strongly influence social thought, the way an individual thinks about and process social information". According to Eggen and Kauchak (2001), positive teachers' attitudes are fundamental to effective teaching. A teacher must be interesting. That is the teacher must work his students into such a state of interest in what the teacher is going to teach him that every other object of attention is banished from his mind. The teacher should also fill the students with devouring curiosity to know what the next steps in connection with the subject are. Eggen and Kauchak (2001) identified a number of teachers' attitudes that will facilitate a caring and supportive classroom environment. They are: enthusiasm, caring, firm, democratic practices to promote students responsibility, use time for lesson effectively, have established efficient routines, and interact freely with students and providing motivation for them.

Research findings on teachers' attitudes (Brunning et al., 1999), established the following facts: Teachers characteristics such as personal teaching efficacy, modeling and enthusiasm, caring and high expectation promote learners' motivation. These same characteristics are also associated with increase in students' achievement (academic performance). High levels of learning may occur as well as learners feeling good about themselves and the material they are learning when teachers use instructional time efficiently. Learning takes place with ease and faster under teachers that are well organized. The way teachers interact with students influences their motivation and attitudes toward school. How students perceive their teachers' attitudes in Nigeria secondary school will be measured based on some of the stated points.

Studies carried out by Yara (2009) have shown that the teachers' method of mathematics teaching and his personality greatly accounted for the students' positive attitude towards mathematics and that, without interest and personal effort in learning mathematics by the students, they can hardly perform well in the subject. The study adopted the descriptive survey design using simple frequency and percentages in analyzing the data. 1542 senior secondary two students randomly selected from 2 schools in each of the senatorial districts from the six states in the South-western part of Nigeria were used. One instrument (SAT) was used while three research questions were answered in the study. The results showed that the students' attitudes towards mathematics were positive and that many of them believed that mathematics is a worthwhile and necessary subject which can help them in their future career. Attitude towards science denotes interest or feeling towards studying science. It is the students' disposition towards 'like' or 'dislike' science while attitude in science means scientific approach assumed by an individual for solving problems, assessing ideas and making decisions.

Review of relevant literature depicts varying opinions and findings on the students' attitude towards science and their performances. According to Keeves (1992) and Postlethwaite and Wiley (1991), attitudes towards science are, in general, highly favoured, indicating strong support for science and the learning of science. There is also consistency across countries and age levels within a country, in the average level of attitude towards science by students. The researchers however concluded that there is marked decline in attitude towards science between the ten-year old and fourteen-year old levels. Greenfield (1995), Parker, Revinue and Fraser (1996), Mullis, Martin, Beaton, Gonsale, Kelly and Smith cited in Yara, 2009 in their findings revealed that in countries where there was an emergent thirst for industrial and technological development, there were very favourable attitudes towards science.

However, in countries where a high level of technological and industrial development had been achieved, the findings showed that attitude towards science were more neutral. Generally, boys held more favourable attitude towards science, the findings concluded. Keeves (1992) asserted that attitude towards science are known to decrease as students' progress through their schooling years. He further submitted that attributes such as enthusiasm, respect for students and personality traits have been shown to influence students' attitude towards science as well as in other subjects. The implication of Keeves' findings is that attention should be given to science teaching early so as to enable students have favourable disposition towards science later in life.

Studies in Nigeria, however, including that of Alao (1988) examined six attitudinal dimensions and their effects on students' achievement. The dimensions were: social implications of science; attitude towards scientific inquiry; normality of scientists; enjoyment of science and science lessons; and leisure interest in science and career interest in science. The result of the study revealed that students have positive attitudes towards sciences, Chemistry inclusive. Odunusi (1994) in assessing the attitude of some science students towards modern orientation in science found that students' attitude to science is negative while gender and class level of the students did not significantly influence students' attitude towards science and process skills acquisition.

Appraisal of the Review

From the above review, very few research works had been carried out on assessing science process skills in Chemistry. The review highlighted some areas of teachers' and students' difficulties in science process skills in Chemistry and other related science subjects. The research findings indicated that students generally have problems on science process skills most especially the higher skills like inferring, predicting, hypothesizing, and so on. Some researchers are of the view that the teacher plays an important role in learning including the acquisition of science process skills. Others attributed the problem to students' readiness or motivation to learn, inadequate laboratory equipment, language, school setting/learning environment, school type, class size and sex.

The review also showed that in order to improve the performance of students and quality of scientists, research studies should be geared towards helping students to acquire science process skills (scientific skills) which will help to solve the problem of rote learning in Chemistry. Some science educators viewed these skills as the generalized intellectual skills needed to learn the concepts and broad principles used in making inductive inferences, and the underlying capabilities needed to practice and understand science. In Chemistry to be specific, the review shows that students are still deficient in science process skills.

Literature on process skills acquisition among students indicates a very serious problem in the level of acquisition. Literature in this area showed that the low level of ability in the performance of process skills activities among students is occasioned by methods of instructing students in Chemistry classes. Researchers generally found that students taught with guided-inquiry method (student-activity centred) performed significantly better than those taught with expository/lecture method (teacher-centred) in process skills tests.

Some of the few researches on process skills centred mostly on general students' performances on science process tests. There were no clear-cut findings on the process skills that are embedded in Chemistry practical questions in senior secondary schools. Also, there were no enough researches on identification of science process skills which students find difficulties acquiring in chemistry. This existing gap is where this study fits in. This study, therefore, intends to broaden our knowledge on areas that Chemistry students encounter difficulty in science process skills acquisition.

CHAPTER THREE

RESEARCH METHOD AND PROCEDURE

This chapter discusses the research design, population for the study, sample and sampling procedure, the research instrument, method of data collection and method of data analysis.

Research Design

The design adopted for the study is a descriptive survey design. The reason for selecting survey as most appropriate for the study is because a questionnaire was employed in the collection of data from a segment of the population and to know what the status quo is.

Generalization was made for the entire population based on the data collected from the sample. The dependent variables were difficulty in Science process skills. The main independent variables were student-related variables (sex and students' attitude) and school or environment-related variables (school location, school type, class size, laboratory adequacy). However, other variables like magnitude and spread of difficulty were considered.

Population of the Study

The population of this study comprised all senior secondary school III (SS III) Chemistry students in the public schools in three senatorial districts of Adamawa and Taraba states. The population was twenty-six thousand, five hundred and seventy one (26,571) students in 296 public senior secondary schools in both Adamawa and Taraba States in Nigeria (Source: Ministry of Education and Statistics, 2012).

Sample and Sampling Technique

The sampling technique used for the study was a multi-stage random sampling technique. The first stage was selection of 25 Local Government Areas (LGAs) that have senior secondary schools offering the basic science subjects from each of the three senatorial districts of Adamawa and Taraba states of Nigeria. The second stage was selection of 36 public schools from the 25 LGAs that have science laboratories and qualified chemistry teachers who had taught the subject for a minimum of 5 years to ensure that teachers' qualification and experience does not confound the result of the study. The third stage was random sampling of 20 SS III Chemistry students from each of the 36 schools. The twenty Chemistry students were randomly selected from each of the sampled schools. The samples of schools selected are reflected in this order: 18 schools from urban and 18 schools from rural; out of these were 5 male schools, 5 female schools, and 26 mixed schools.

The schools were selected according to school location (urban and rural) and school type that is, boys only, girls only and coeducational schools to ensure the representativeness of both sexes in the sample.36 schools (10 single sex and 26 mixed schools) were selected out of the 296 secondary schools in Adamawa and Taraba States. Out of these 36 schools, 20 students who has been coming regularly for classes were selected by the teachers giving a sample size of seven hundred and twenty (720) students. Out of this total number sampled, 202 males and 196 females were selected for the urban schools and 164 males 158 females were selected for the rural schools, giving a total number of 720 students. The table of distribution of sample by school location, school type and sex is shown in Appendix III, while the sample of schools is in Appendix V.

Research Instrument

The research instrument that was used for this study is:

Science Process Skills Knowledge Test in Chemistry (SPSKTC) (see Appendix 1).The test (SPSKTC) consisted of two sections. Section A demanded personal information on the school and respondent (bio data). Section B consisted of 70 questions on 15 items which include 6 basic or lower skills (observing, classifying, measuring, communicating, recording, using number relationships) and 9 higher or integrated skills (hypothesizing, predicting, inferring, identifying/controlling variables, interpreting data, defining operationally, experimenting, manipulating, and building mental models). The table of specification of items on SPSKTC which guided the instrument preparation is shown on Appendix IV. The SPSKTC was a test of knowledge on 15 Science process skills, having options A-D where students are expected to choose only one correct answer. Each correct answer was assigned 1mark while the incorrect (wrong) answer was assigned 0mark. The mean scores for each process skill by each student were collated by counting the number of students that experienced difficulty in process skills acquisition and expressed in simple percentages. Tests of skills involve testing the application of students' knowledge to problems or situations so as to assess the level of student knowledge in comparison to a particular competence which was

15 items or process skills. The test of knowledge on Science process skills covers both the basic and integrated skills and these were adapted from WAECSSCE Alternative to practical Chemistry past questions of 10 years: 2002 -2011.

Validity of Instrument

The Science process skills Knowledge Test in Chemistry(SPSKTC) was subjected to both content and face validity by three experts in science education and two in test and measurement. Two Chemistry teachers who had taught this subject for more than eight years also helped in the validation of the instrument. The experts rated the relevance of each item as an indicator of the construct and items not relevant to the construct being measured, were rewritten or eliminated. The experts also pointed out any aspects of the construct that were not covered adequately in order to increase the construct validity of the scale. The experts also rated the clarity and conciseness of each item.

Reliability of Instrument

The items were actually tested on a sample of the target population to determine the reliability. The items were pre-tested using 20 SS III Chemistry students in two randomly selected secondary schools in Adamawa and Taraba States. These students were drawn from Government Day Senior Secondary School Magami and Model Secondary School, Federal College of Education, Yola. The data obtained was subjected to Kuder Richardson formula 21 to obtain the correlation value. A correlation coefficient of 0.78 was obtained which was considered adequate for this study (see Appendix II).

Administration and Collection of Data

Official permission was duly obtained from the heads of the 36 schools of the subjects that participated in this study. The Chemistry teachers in each school were used as the research assistants. Before the administration of the test, the teachers were given orientation on the purpose of the study and on the science process skills which should be made applicable in student-activity classrooms as they prepare for the SSCE examination. The school syllabus has Chemistry quantitative and qualitative analysis for 8 weeks and strategies were made applicable for teachers to ensure that the SS III Chemistry students have knowledge of the process skills. All the 36 schools used for this study have Chemistry laboratories, though some of them are not properly equipped; and also have qualified Chemistry teachers; so as to ensure that the result of the study is not distorted

The Science process skills Knowledge Test in Chemistry (SPSKTC) was administered with the help of the Chemistry teachers and the researcher in the schools. The questionnaires were collected from the students on the spot on completion by the researcher and chemistry teachers in the selected schools. Five weeks was used to administer the questionnaire and collection of data.

Method of Data Analysis

After the administration of the SPSKTC, students' answers were collected and scored. The data collected were arranged and analyzed so as to answer the research questions and test the stated hypotheses. Descriptive statistics in terms of means, frequencies, percentages and standard deviation were used to analyze the response measures on SPSKTC. The level of difficulty of a particular process skill was determined by the value of the mean as follows: means scores less than 50 (< 50) were classified as 'Difficult', and means scores equal to or above 50 (≥ 50) as 'Simple'. Each student was scored on each of the science process skills before the individual scores were aggregated to form a composite means scores. The data collected were analyzed using means and t-test. The hypotheses were tested at 0.05 level of significance. Hypotheses 1-7 were tested with t-test statistics which were calculated with SPSS (Statistical Package for Social Sciences) 16.0 version.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION

This chapter is discussed under the following sub-headings:

i. Answering of research questions

ii. Testing of research hypotheses

iii. Discussion of Results

Answering of Research Questions

Research Question 1:

What specific science process skills do Chemistry students experience difficulty in acquiring?

Table 4.1 was used in answering research question 1.

Table 4.1: Areas of Chemistry students' difficulty in science process skills acquisition

Type of Skills	Science Process Skills	N	Mean	Std. Deviation	Remarks

Basic Skills	Observing	720	26.7160	14.82931	Difficult
	Classifying	720	45.9349	19.66844	Difficult
	Measuring	720	53.6389	15.79009	Simple
	Communicating	720	38.8889	17.13528	Difficult
	Recording	720	38.9167	18.58540	Difficult
	Using Number Relationships	720	35.7939	20.79647	Difficult
Integrated Skills	Formulating Hypotheses	720	36.9444	19.75080	Difficult
	Predicting	720	32.6736	16.60422	Difficult
	Inferring	720	28.7500	16.98297	Difficult
	Identifying/Controlling Variables	720	27.9824	15.44749	Difficult
	Interpreting Data	720	44.1111	19.98021	Difficult
	Defining Operationally	720	42.8125	18.54138	Difficult
	Experimenting	720	37.9722	19.21402	Difficult
	Manipulating Techniques	720	51.0284	18.41318	Simple
	Building Mental Models	720	51.8619	18.92849	Simple

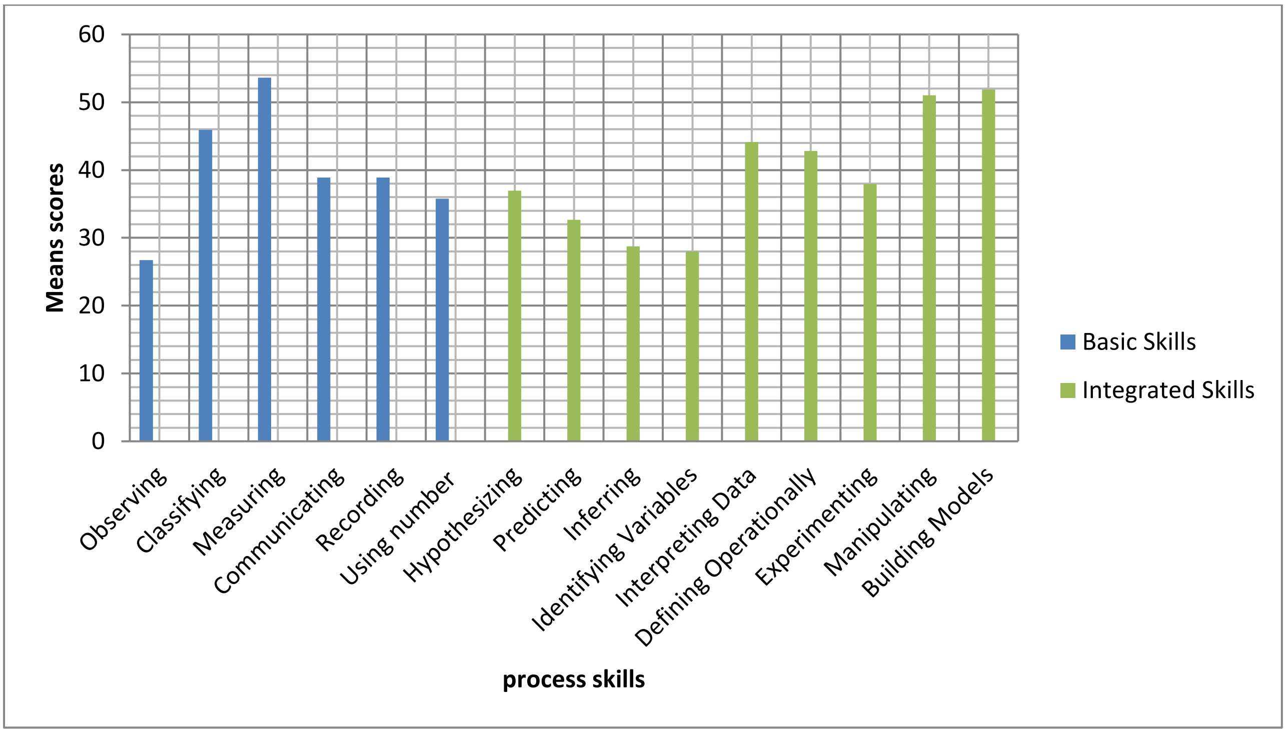

Figure 4.1: Areas of Chemistry students' difficulty in science process skills acquisition

The analysis showed in Table 4.1 and Fig. 4.1 revealed the specific science process skills that students experience difficulty in acquiring in this order: observing (26.72), identifying/controlling variables (27.98), inferring (28.75), predicting (32.67), using number relationships (35.79), formulating hypotheses (36.94), experimenting (37.97), communicating (38.89), recording (38.92), defining operationally (42.81), interpreting data (44.11), and classifying (45.93); while manipulating technique (51.03), building mental models (51.86) and measuring (53.64) as simple. Out of these 5 basic skills with mean scores of 39.98 and 7 integrated skills with mean scores of 39.35 were found difficult in acquiring by Chemistry students. Out of the 15 science process skills, 12 (80%) were found difficult by students in acquiring.

Research Question 2:

Does sex influence Chemistry students’ difficulty in science process skills acquisition?

Table 4.2 was used to answer research question 2:

Table 4.2: Means scores and t-test summary table for process skills difficulty experienced by male and female Chemistry students

Process skills	Sex	N	Mean	Std. Deviation	df	t	∝
Observing	Male	366	26.8269	14.682	718	.637	0.05
	Female	354	26.5590	14.831			
	Male	366	45.7285	19.817	718	.484	0.05
Classifying	Female	354	46.1483	19.539			
Measuring	Male	366	54.4262	16.736	718	.458	0.05
	Female	354	58.4746	19.482			
	Male	366	41.1202	19.401	718	.677	0.05
Communicating	Female	354	39.4068	18.362			
	Male	366	39.2896	18.328	718	.635	0.05
Recording	Female	354	38.4746	18.710			
	Male	366	38.5792	19.533	718	.639	0.05
Using number relationships	Female	354	38.4746	20.111			
	Male	366	35.8470	19.023	718	.638	0.05
Formulating hypotheses	Female	354	38.0791	20.441			
	Male	366	33.8115	17.038	718	.644	0.05
Predicting	Female	354	34.6751	16.935			
	Male	366	27.5273	16.305	718	.637	0.05
Inferring	Female	354	24.4350	13.817			
	Male	366	27.1457	14.742	718	.794	0.05

Identifying/Controlling variables	Female	354	29.0077	16.071			
Interpreting data	Male	366	43.9891	19.985	718	.553	0.05
	Female	354	44.2373	20.003			
Defining operationally	Male	366	43.0328	18.853	718	.522	0.05
	Female	354	42.5847	18.237			
	Male	366	34.5355	18.921	718	.528	0.05
Experimenting	Female	354	41.5254	18.891			
	Male	366	52.9246	18.360	718	.520	0.05
Manipulating techniques	Female	354	51.1621	18.464			
	Male	366	53.7445	18.211	718	.558	0.05
Building mental models	Female	354	52.9154	19.4778			

Total mean scores (Male) =42.20 Total mean scores (Female) =40.40

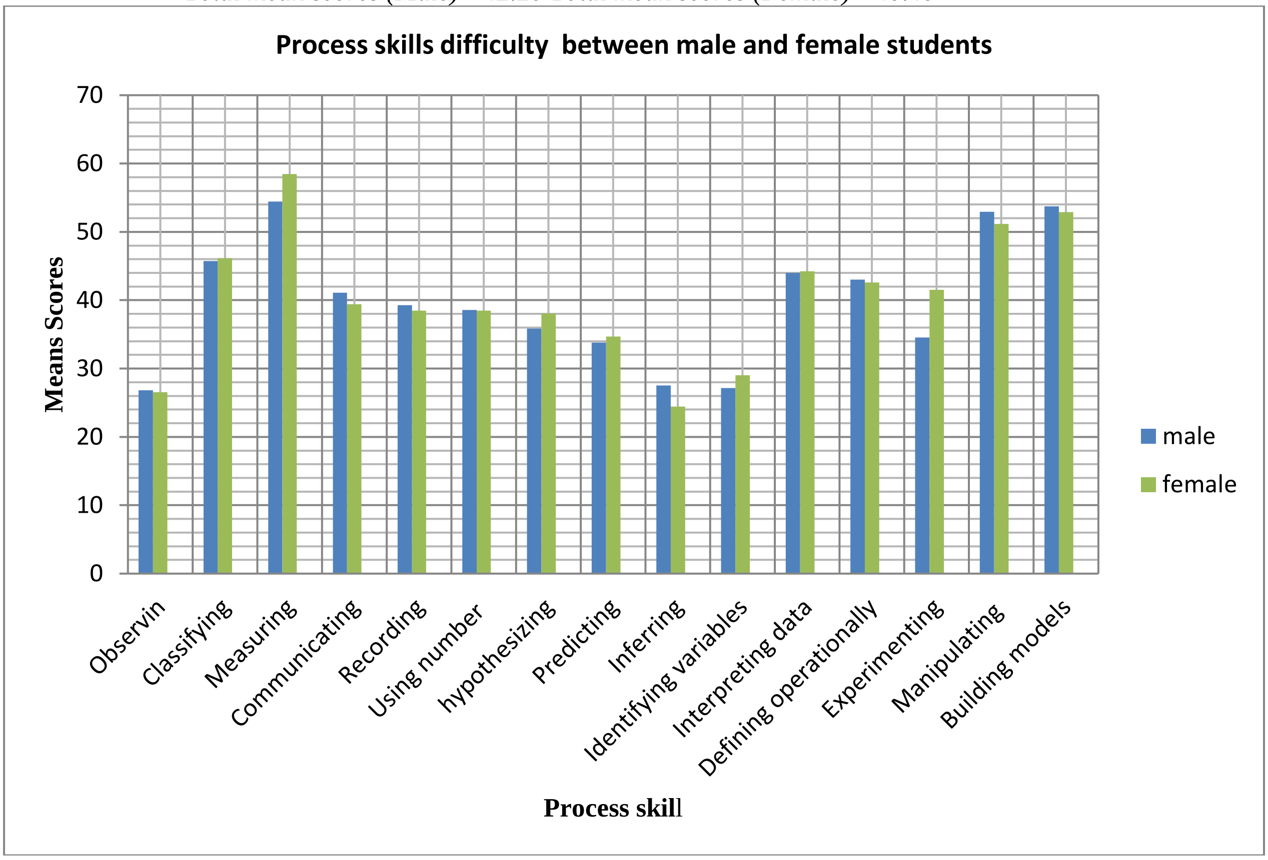

Figure 4.2 Process skills difficulty between male and female students

The analysis showed in Table 4.2 and Fig. 4.2 revealed that the total mean scores of the male students who experienced difficulty in science process skills acquisition was 42.20 while; the mean scores of the female students who experienced difficulty in science process skills acquisition was 40.40. Both males and females experienced insignificant difficulty in process skills acquisition. Also in Table 4.2, the t values for sex for the 15 process skills are .637, .484, .458, .677, .635, .639, .638, .644, .637, .794, .553, .522, .528, .520 and .558 which are greater than; 0.05 level of significance. This shows that sex have negligible influence on students' difficulty in science process skills acquisition but was tested with hypothesis 2.

Research Question 3

Does school location influence Chemistry students' difficulty in science process skills acquisition?

The data to answer research three is presented on Table 4.3.

Table 4.3: Means scores and t-test summary table for process skills difficulty experienced by Chemistry students in Urban and Rural schools

Process skills	School Location	N	Mean	Std. Deviation	df	t	∝
Observing	Urban	360	29.4966	15.78427	718	.658	0.05
	Rural	360	35.7016	10.91016			
	Urban	360	45.3329	19.64620	718	.448	0.05
Classifying	Rural	360	46.5369	19.69955			
Measuring	Urban	360	51.9444	16.30480	718	.820	0.05
	Rural	360	55.3333	15.09118			
	Urban	360	39.4444	19.02124	718	.664	0.05
Communicating	Rural	360	41.1111	18.77558			
	Urban	360	34.5000	17.59257	718	.660	0.05
Recording	Rural	360	43.2778	18.38404			
	Urban	360	34.7222	18.99804	718	.639	0.05
Using number relationships	Rural	360	42.5556	19.86366			
	Urban	360	40.9444	20.03332	718	.772	0.05
Formulating hypotheses	Rural	360	32.9444	18.65079			
	Urban	360	33.1250	16.84431	718	.620	0.05
Predicting	Rural	360	30.5556	12.67099			
	Urban	360	25.1389	14.33222	718	.688	0.05
Inferring	Rural	360	26.8056	16.05842			
	Urban	360	29.7282	15.91214	718	.835	0.05
Identifying/Controlling variables	Rural	360	26.2089	14.67257			
Interpreting data	Urban	360	43.3333	20.08339	718	.564	0.05
	Rural	360	44.9444	19.88819			
Defining operationally	Urban	360	42.2222	18.14690	718	.639	0.05
	Rural	360	43.0556	18.48276			
	Urban	360	33.9444	18.46467	718	.684	0.05
Experimenting	Rural	360	42.0000	19.12865			
	Urban	360	53.8067	18.05822	718	.466	0.05
Manipulating techniques	Rural	360	48.2501	18.36993			
	Urban	360	52.3248	18.97209	718	.457	0.05
Building mental models	Rural	360	51.3063	19.06948			

Total mean scores (Urban) =39.33Total mean scores (Rural) =40.40

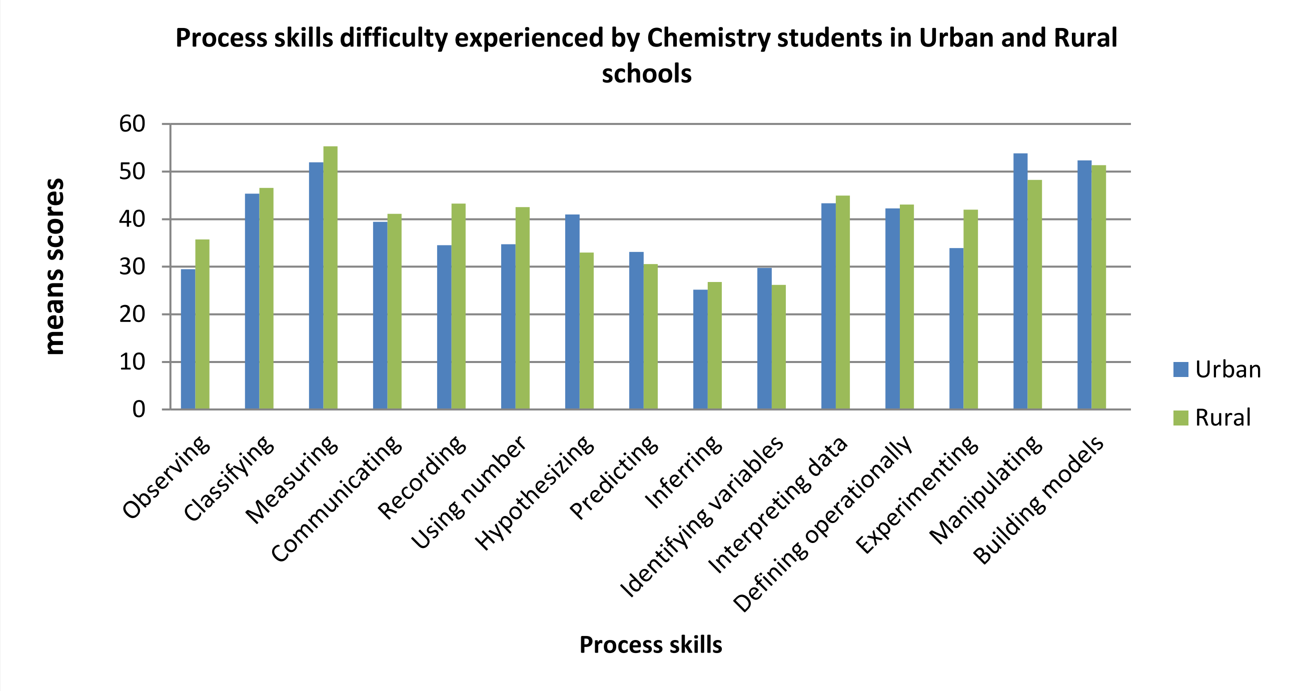

Figure 4.3: Process skills difficulty between students in urban and rural schools

The analysis showed in Table 4.3 and Fig. 4.3 also revealed that the mean scores of the urban students who experienced difficulty in science process skills acquisition was 39.33 while; the mean scores of the rural students who experienced difficulty in science process skills acquisition was 40.40. Table 4.3 showed the t values for school location for the 15 process skills which are .658, .448, .677, .820, .664, .660, .639, .772, .620, .688, .535, .564, .639, .684, .564, .466 and .457 which are greater than 0.05. Both urban and rural students experienced insignificant difficulty in process skills acquisition. This shows that school location have negligible influence on students' difficulty in science process skills acquisition but was tested with hypothesis 3.

Research Question 4:

Does school type influence Chemistry students' difficulty in science process skills acquisition?

Table 4.4 was used to answer research questions 4:

Table 4.4: Means scores and t-test summary table of process skills difficulty experienced by Chemistry students in Single-sex and Mixed schools

Process skills	School Type	N	Mean	Std. Deviation	df	t	∝
Observing	single sex	200	28.36	16.119	718	.657	0.05
	mixed	520	29.29	15.489			
Classifying	single sex	200	46.57	22.138	718	.484	0.05
	mixed	520	45.89	18.934			
Measuring	single sex	200	52.20	16.263	718	.458	0.05
	mixed	520	54.19	15.585			
Communicating	single sex	200	41.75	20.985	718	.486	0.05
	mixed	520	39.66	17.901			
Recording	single sex	200	42.20	20.129	718	.620	0.05
	mixed	520	36.54	16.896			
Using number relationships	single sex	200	41.20	19.505	718	.879	0.05
	mixed	520	32.50	18.412			
Formulating hypotheses	single sex	200	35.60	20.066	718	1.000	0.05
	mixed	520	35.46	20.272			
Predicting	single sex	200	33.63	17.291	718	.953	0.05
	mixed	520	32.26	16.171			
Inferring	single sex	200	27.63	16.319	718	.658	0.05
	mixed	520	25.63	14.750			
Identifying/Controlling variables	single sex	200	29.51	15.199	718	.666	0.05
	mixed	520	27.40	15.517			
Interpreting data	single sex	200	44.20	20.109	718	.553	0.05
	mixed	520	44.15	20.011			
Defining operationally	single sex	200	41.88	17.171	718	.586	0.05
	mixed	520	42.12	17.361			
Experimenting	single sex	200	39.50	19.277	718	.555	0.05
	mixed	520	37.38	19.176			
Manipulating techniques	single sex	200	51.18	18.269	718	.526	0.05
	mixed	520	51.04	18.482			
Building mental models	single sex	200	51.68	19.702	718	.554	0.05
	mixed	520	51.93	18.641			

Total mean scores (single sex =40.45 Total mean scores (mixed) =39.03

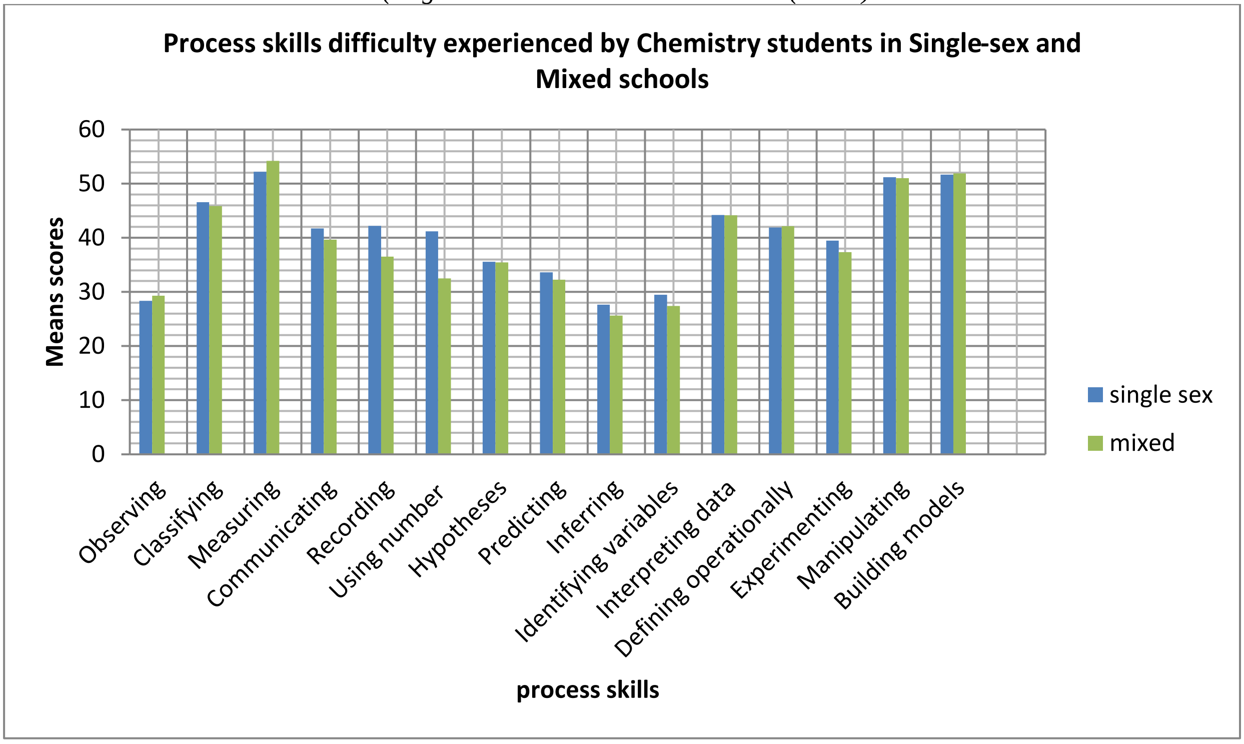

Figure 4.4: Process skills difficulty between students in single-sex and mixed schools

The analysis showed in Table 4.4 and Fig. 4.4 also revealed that the mean scores of the single sex schools students who experienced difficulty in science process skills acquisition was 40.45 while; the mean scores of the mixed schools students who experienced difficulty in science process skills acquisition was 39.03. Table 4.4 also showed the t values for school type for the 15 process skills which are .657, .484, .458,.486, .620, .979, 1.000,.953, .668, .666, .553, .586, .555, .526 and .554 which are greater than 0.05. Both single and mixed schools students experienced insignificant difficulty in process skills acquisition. This showed that school type have negligible influence on students' difficulty in science process skills acquisition but was tested with Ho4.

Research Question 5:

Does class size influence Chemistry students' difficulty in science process skills acquisition?

Table 4.5 was used to answer research questions 5:

Table 4.5: Means scores and t-test summary table for process skills difficulty experienced by Chemistry students in large class and small class sizes

Process skills	Class size	N	Mean	Std. Deviation	df	t	∝
Observing	large	420	23.8937	12.75058	718	.000	0.05
	small	300	36.6740	16.01602			
	large	420	41.3177	18.79779	718	.001	0.05
Classifying	small	300	52.3411	18.98985			
Measuring	large	420	49.9048	15.60217	718	.003	0.05
	small	300	58.8667	14.54030			
	large	420	35.8333	17.49247	718	.000	0.05
Communicating	small	300	47.8333	18.38747			
	large	420	30.7619	17.04663	718	.001	0.05
Recording	small	300	46.2667	18.45347			
	large	420	34.7619	19.07629	718	.000	0.05
Using number relationships	small	300	44.0667	19.58078			
	large	420	30.3333	17.00437	718	.000	0.05
Formulating hypotheses	small	300	46.8000	19.74147			
	large	420	28.3929	12.76651	718	.001	0.05
Predicting	small	300	39.5000	19.23930			
	large	420	21.6667	13.40870	718	.002	0.05
Inferring	small	300	32.8333	15.87384			
	large	420	25.4416	13.09896	718	.000	0.05
Identifying/Controlling variables	small	300	32.7288	17.47558			
Interpreting data	large	420	38.9524	18.50879	718	.000	0.05
	small	300	51.3333	19.75322			
Defining operationally	large	420	39.2857	15.39346	718	.001	0.05
	small	300	48.2500	17.79728			
	large	420	26.8571	13.70081	718	.000	0.05
Experimenting	small	300	54.2667	14.22921			
	large	420	48.6604	18.44942	718	.002	0.05
Manipulating techniques	small	300	56.4552	17.43564			
	large	420	49.0573	18.75935	718	.003	0.05
Building mental models	small	300	59.5667	16.84533			

Total mean scores (large class size) =35.01 Total mean scores (small class size) =50.80

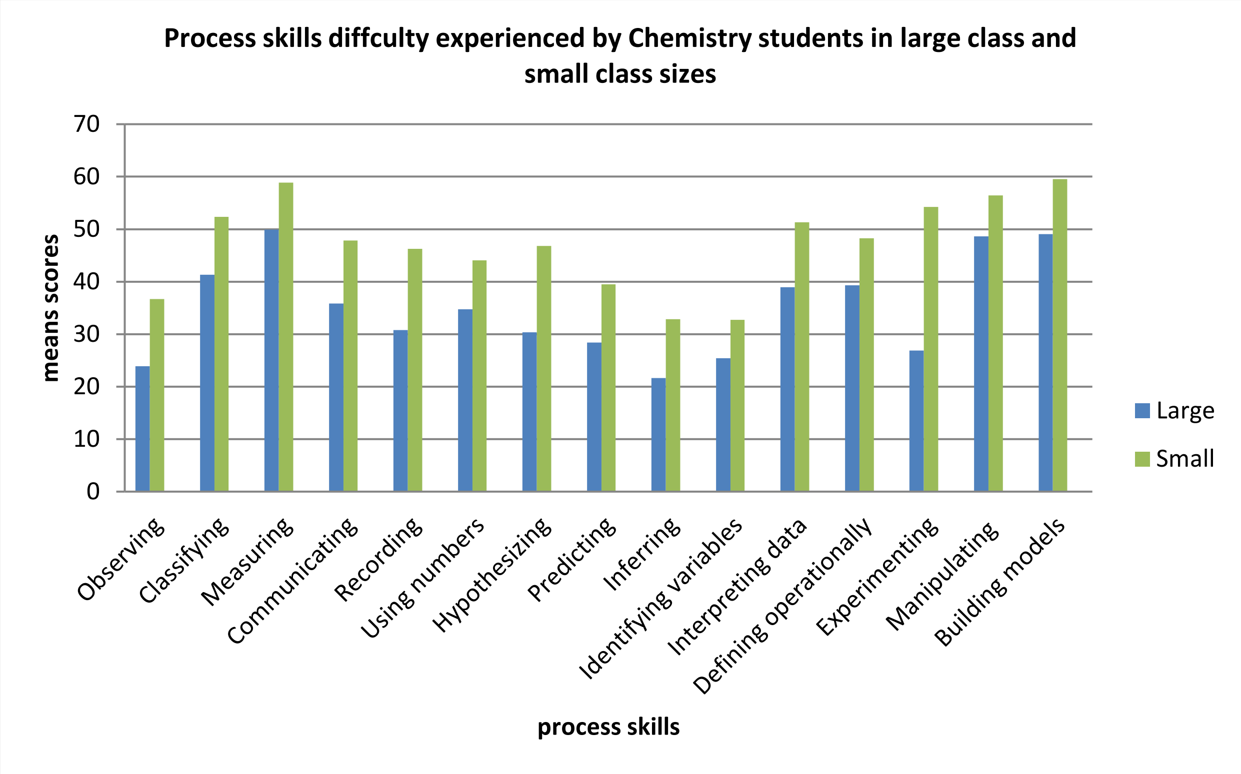

Figure 4.5: Process skills difficulty experienced by Chemistry students in large class and small class sizes

The analysis showed in Table 4.5 and Fig. 4.5 revealed that the mean scores of students that are from large class sizes that experienced difficulty in acquiring Science process skills were 35.01; while the mean scores of students that are from small class sizes who experienced difficulty in acquiring Science process skills was 50.80. Table 4.5 also showed the t values for class size for the 15 process skills which are .000, .001, .003, .000, .001, .000, .000, .001, .002, .000, .000, .001, .000, .002 and .003 which are less than 0.05. This shows that class size have great influence on students' difficulty in Science process skills acquisition since the mean percent is significant; but was tested with Ho5.

Research Question 6:

Does students' attitude towards Chemistry influence students' difficulty in science process skills acquisition?

Table 4.6 was used to answer research questions 6:

Table 4.6: Means scores and t-test summary table for process skills difficulty experienced by students having positive and negative attitudes towards

Chemistry

Process skills	Attitude	N	Mean	Std. Deviation	df	t	∝
Observing	Positive	540	37.8779	12.53947	718	.000	0.05
	Negative	180	27.6907	13.78071			
	Positive	540	54.2667	14.22921	718	.006	0.05
Classifying	Negative	180	26.3596	13.83122			
Measuring	Positive	540	59.1481	13.34626	718	.018	0.05
	Negative	180	42.0000	14.19733			
	Positive	540	51.3333	19.75322	718	.000	0.05
Communicating	Negative	180	32.7778	17.38668			
	Positive	540	49.7407	18.89153	718	.006	0.05
Recording	Negative	180	29.6667	17.10631			
	Positive	540	49.0000	17.64734	718	.002	0.05
Using number relationships	Negative	180	28.5556	18.43370			
	Positive	540	40.2963	19.79264	718	.001	0.05
Formulating hypotheses	Negative	180	27.1111	15.76677			
	Positive	540	43.1019	16.18420	718	.000	0.05
Predicting	Negative	180	30.0000	15.72281			
	Positive	540	28.0093	15.12072	718	.000	0.05
Inferring	Negative	180	20.0000	14.08276			
	Positive	540	29.9751	15.18078	718	.001	0.05
Identifying/Controlling variables	Negative	180	21.9488	14.47423			
Interpreting data	Positive	540	52.2222	17.36508	718	.000	0.05
	Negative	180	27.0000	16.97517			
Defining operationally	Positive	540	54.2667	14.22921	718	.002	0.05
	Negative	180	31.5278	13.04373			
	Positive	540	46.1481	20.11046	718	.000	0.05
Experimenting	Negative	180	28.6667	18.56289			
	Positive	540	55.3811	17.17086	718	.020	0.05
Manipulating techniques	Negative	180	44.6382	19.35424			
	Positive	540	53.9610	18.13054	718	.011	0.05
Building mental models	Negative	180	49.0023	20.45768			

Total mean scores (Positive) =47.0 (Negative) =24.88

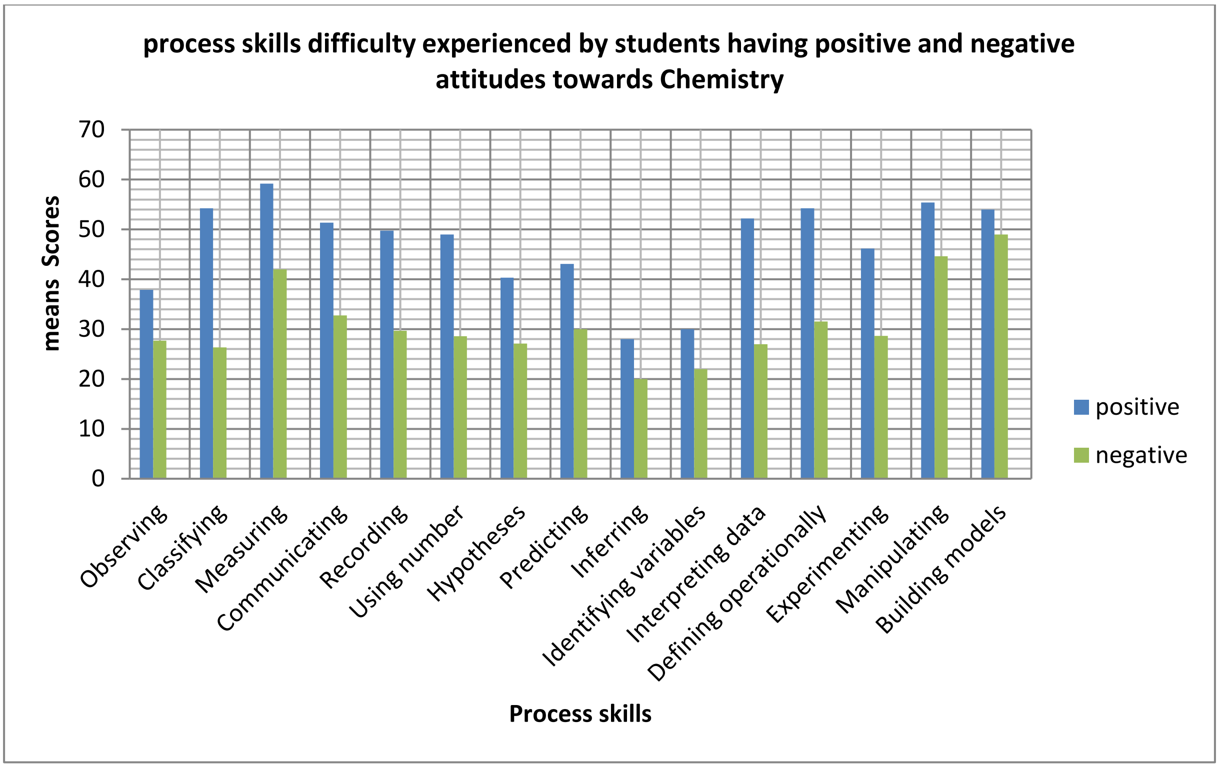

Figure 4.6: Process skills difficulty experienced by students having positive and negative attitudes towards Chemistry

The analysis showed in Table 4.6 and Fig 4.6 revealed that the mean scores of students with positive attitude towards Chemistry who experienced difficulty in acquiring science process skills was 47.0; while the mean scores of students with negative attitude towards Chemistry who experienced difficulty in acquiring Science process skills was 24.88. Table 4.6 also showed the t values for students' attitude for the 15 process skills which are .000, .006, .018, .000, .006, .002, .001, .000, .000, .001, .000, .002, .000, .020 and .011 which are less than 0.05. This shows that students' attitude have great influence on students' difficulty in science process skills acquisition since the mean percent is significant; but was tested with Hypothesis 6.

Research Question 7:

Does laboratory adequacy influence Chemistry students' difficulty in science process skills acquisition?

Table 4.7: Means scores and t-test summary table for process skills difficulty experienced by Chemistry students in schools with well-equipped and ill-equipped laboratories

Process skills	Lab Type	N	Mean	Std. Deviation	df	t	∝
Observing	well-equipped	480	35.1806	15.10240	718	.001	0.05
	ill-equipped	240	23.6158	12.59035			
	well-equipped	480	56.1250	15.04291	718	.017	0.05
Classifying	ill-equipped	240	38.2020	19.15524			
Measuring	well-equipped	480	56.1250	15.04291	718	.028	0.05
	ill-equipped	240	49.1667	15.71628			
	well-equipped	480	43.4896	18.22098	718	.033	0.05
Communicating	ill-equipped	240	33.5417	17.41562			
	well-equipped	480	46.1667	17.25086	718	.000	0.05
Recording	ill-equipped	240	29.5833	15.73291			
	well-equipped	480	45.2917	18.80341	718	.000	0.05
Using number relationships	ill-equipped	240	30.0000	18.01905			
	well-equipped	480	41.5833	19.70538	718	.002	0.05
Formulating hypotheses	ill-equipped	240	35.8333	20.92358			
	well-equipped	480	51.3333	19.75322	718	.000	0.05
Predicting	ill-equipped	240	37.2917	17.54679			
	well-equipped	480	32.3438	15.04955	718	.000	0.05
Inferring	ill-equipped	240	19.1667	15.92127			
	well-equipped	480	34.7292	16.69898	718	.001	0.05
Identifying/Controlling variables	ill-equipped	240	24.7966	14.22212			
Interpreting data	well-equipped	480	49.1667	15.71628	718	.003	0.05
	ill-equipped	240	40.5000	20.11889			
Defining operationally	well-equipped	480	56.1250	15.04291	718	.035	0.05
	ill-equipped	240	37.3958	15.16953			
	well-equipped	480	42.5417	19.75313	718	.000	0.05
Experimenting	ill-equipped	240	36.4167	15.59400			
	well-equipped	480	55.2885	17.36559	718	.028	0.05
Manipulating techniques	ill-equipped	240	43.6196	18.19438			
	well-equipped	480	55.3578	18.75818	718	.026	0.05
Building mental models	ill-equipped	240	44.8699	17.29198			

Total mean scores (well-equipped) =48.70 (ill-equipped) =34.93

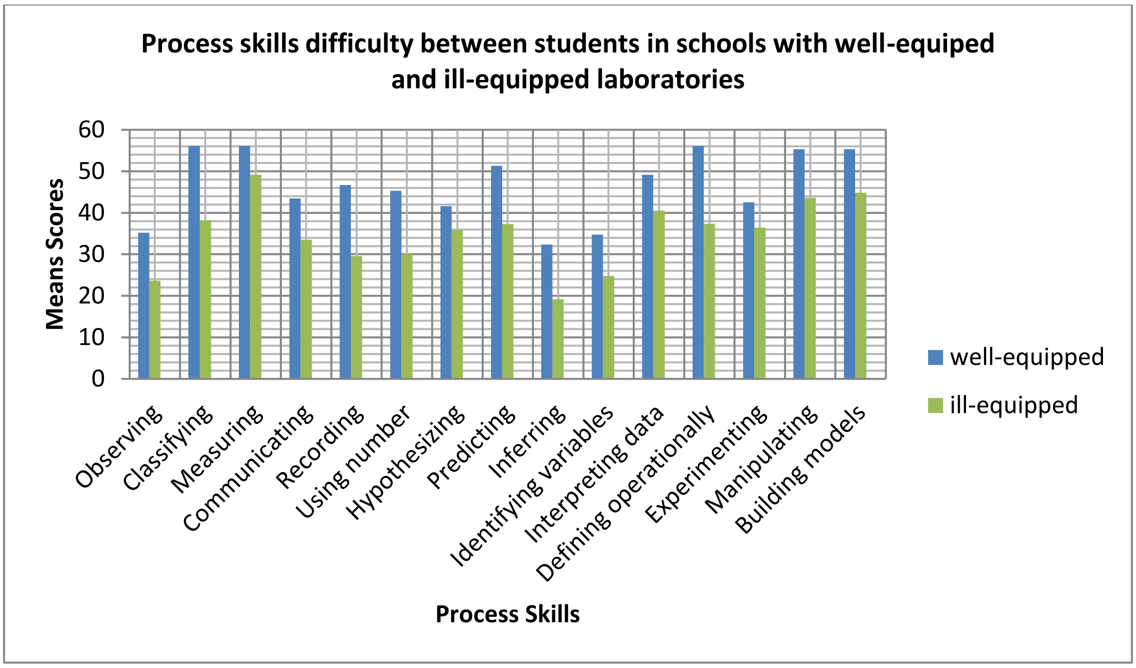

Figure 4.7: Process skills difficulty between students in schools with well-equipped and ill-equipped laboratories

The analysis showed in Table 4.7 and Fig. 4.7 revealed that the mean scores of students in schools with well-equipped laboratories who experienced difficulty in acquiring science process skills was 48.70; while the mean percentage of students in schools with ill-equipped laboratories who experienced difficulty in acquiring Science process skills was 34.93. Table 4.7 also showed the t values for laboratory adequacy for the 15 process skills which are .001, .017, .028, .033, .000, .000, .002, .000, .000, .001, .003, .035, .000, .028 and .026 which are less; 0.05 level of significance. This shows that laboratory adequacy have great influence on students' difficulty in science process skills acquisition since the mean scores was significant; but was tested with Ho 7.

Testing of Research Hypotheses

Hypotheses 1:

There is no significant difference in the mean difficulty of chemistry students' scores between basic and integrated science process skills.

Table 4.8 was used to answer research hypothesis 2:

Table 4.8: t-test summary table comparing mean difficulty of chemistry students' scores between basic and integrated science process skills

	Type of Skills	N	Mean	Std. Deviation	df	t	∝	$p \leq .05$	Decision
Scores	Basic Skills	720	40.0020	19.77573	718	.483	0.05	.637	Not Significant
	Integrated Skills		39.3485	20.05593					

**Significant at $p \leq .05$* Decision=Not Significant at p> 0.05 level ($H0_1$ Not rejected or Retained)

As indicated in Table 4.8 the t value for skills type is .483 not significant at p =.637: p> 0.05 level of significance; showing that the significant (2-tailed) is greater than 0.05 showing non-significant difference between students' difficulty in basic and integrated skills, hence the null hypothesis was retained. Thus the hypothesis 1, no difference between students' difficult in basic and integrated skills was not rejected.

Hypothesis 2

There is no significant difference in the mean difficulty of process skills scores between male and female Chemistry students.

Table 4.4: t-test summary table comparing process skills difficulty experienced by male and female Chemistry students

	Sex	N	Mean	Std. Deviation	df	T	∝	$p \leq .05$	Decision
Scores	Male	366	39.79	20.166	718	.731	0.05	.465	Not Significant
	female	354	40.08	20.319					

**Significant at $p \leq .05$* Decision=Not Significant at p>0.05 level ($H0_2$ Not rejected or Retained)

In Table 4.9, the t-ratio for sex is .731 is not significant at p =.465: p> 0.05 level of significance; showing that the significant (2-tailed) is less than .05. The result showed that there was no significant difference in the mean difficulty process skills scores between male and female Chemistry students. Based on this, hypothesis two was not rejected.

Hypothesis 3

There is no significant difference in the mean difficulty of process skills scores between Chemistry students in urban and in rural schools.

Table 4.10: t-test summary table comparing process skills difficulty experienced by Chemistry students in Urban and Rural schools

	school location	N	Mean	Std. Deviation	df	t	∝	$p \leq .05$	Decision
Scores	urban	360	39.34	19.884	718	3.622	0.05	.637	Not Significant
	rural	360	40.71	19.388					

**Significant at $p \leq .05$* Decision=Not Significant at p> 0.05 level ($H0_3$ Not Rejected or Retained)

From Table 4.10, the t-ratio for school location is 3.622 at p=.637; p>0.05; showing that the significant (2-tailed) is greater than .05 hence the null hypothesis Ho3 was not rejected. This showed that there was no significant difference in the mean difficulty of process skills scores between Chemistry students in urban and rural schools.

Hypothesis 4:

There is no significant difference in the mean difficulty of process skills scores between Chemistry students in single sex and in mixed schools.

Table 4.11: t-test summary table comparing process skills difficulty experienced by Chemistry students in Single-sex and Mixed schools

	School Type	N	Mean	Std. Deviation	df	t	∝	$p \leq .05$	Decision
Scores	Single sex	200	40.47	20.244	718	3.382	0.05	.586	Not Significant
	Mixed	520	39.03	19.683					

**Significant at $p \leq 05$* Decision=Significant at P> 0.05 level ($H0_4$ Not Rejected or Retained)

As indicated in Table 4.11, the t-ratio for school type is 3.382 at p=.586; p>0.05; showing that the significant (2-tailed) is greater than .05 hence the null hypothesis Ho4 was not rejected. The result therefore showed that there was no significant difference in the mean difficulty process skills scores between Chemistry students in single sex schools and mixed schools.

Hypothesis 5:

There is no significant difference in the mean difficulty of process skills scores between Chemistry students in small-class size and in large-class size.

Table 4.12: t-test summary table comparing process skills difficulty experienced by

Chemistry students in large class and small class sizes

	Class size	N	Mean	Std. Deviation	df	t	∝	$p \leq .05$	Decision
Scores	Large	480	35.011	18.614	718	-30.500	0.05	.000	Significant
	Small	300	46.362	19.702					

**Significant at $p \leq .05$* Decision= Significant at $p < 0.05$ level ($H0_5$ Rejected)

As indicated in Table 4.12, the t-ratio for class size is -30.500 at p=.000: p<0.05; showing that the significant (2-tailed) is less than .05 hence the null hypothesis Ho5 was rejected. The result showed that there was a significant difference in the mean difficulty process skills scores between Chemistry students in small-class size and those in large-class size.

Hypothesis 6:

There is no significant difference in the mean difficulty of process skills scores between Chemistry students with negative attitude and those with positive attitude towards Chemistry.

Table 4.13: t-test summary table comparing process skills difficulty experienced by students with positive attitude and those with negative attitudes towards Chemistry

	Type of attitude	N	Mean	Std. Deviation	df	t	∝	$p \leq .05$	Decision
Scores	Positive	540	42.21	19.780	718	-3.910	0.05	.000	Significant
	Negative	180	35.69	24.598					

**Significant at $p \leq .05$* Decision= Significant at $p < 0.05$ level ($H0_6$ Rejected)

As indicated in Table 4.13, the t-ratio for students' attitude towards chemistry is -3.910 at p=0.000; p<0.05; showing that the significant (2-tailed) is less than .05 hence the null hypothesis Ho6 was rejected. This shows that there is a significant difference in the mean difficulty process skills scores between Chemistry students with negative attitude and those with positive attitude towards Chemistry.

Hypothesis 7:

There is no significant difference in the mean difficulty of process skills scores between Chemistry students who were taught with well-equipped laboratories and those who were taught with ill-equipped laboratories.

The data to answer Hypothesis seven is presented on Table 4.14.

Table 4.14: t-test summary table comparing process skills difficulty experienced by Chemistry students in schools with well-equipped and ill-equipped laboratories

		N	Mean	Std. Deviation	df	t	∝	$p \leq .05$	Decision
Scores	Well-equipped	480	42.1577	20.19856	718	-19.329	0.05	.000	Significant
	ill-equipped	240	34.3745	18.74864					

**Significant at $p \leq .05$* Decision= Significant at p< 0.05 level ($H0_7$ Rejected)

As indicated in Table 4.14, the t-ratio for laboratory adequacy is -19.329 at p=0.000: p<0.05; showing that the significant (2-tailed) is less than .05 hence the null hypothesis Ho7 was rejected. This shows a significant difference in the mean difficulty process skills scores between Chemistry students who were taught with well-equipped laboratories and those taught with ill-equipped laboratories.

Discussion of Results

This study answered 7 questions and tested 7 hypotheses on the analysis of senior secondary school students' experienced difficulty in science process skills acquisition. The analysis of the data collected gave rise to the following findings which are discussed.

The findings of the study as presented in Table 4.1 revealed the specific science process skills that students experience difficulty in acquiring in this order: observing (26.72), identifying/controlling variables (27.98), inferring (28.75), predicting (32.67), using number relationships (35.79), formulating hypotheses (36.94), experimenting (37.97), communicating (38.89), recording (38.92), defining operationally (42.81), interpreting data (44.11), and classifying (45.93); while manipulating technique (51.03), building mental models (51.86) and measuring (53.64) as simple. Out of these 5 basic skills with mean scores of 39.98 and 7 integrated skills with mean scores of 39.35 were found difficult in acquiring by Chemistry students respectively. Out of the 15 science process skills, 12 (80%) were found difficult by students in acquiring. This variation in difficulty levels of Science process skills can be attributed to the type of activities to which the students were exposed. Adeyemi (2000) found that not all the process skills in Chemistry are found difficult by students. Igboanugo (2004) work showed that teachers are generally aware of the low level of process skills acquisition by students in Chemistry. In addition, the findings of this study agreed with Okebukola (1999) findings which shown that students generally do poorly in Science process skills having very low mean scores. The findings of this study which indicated that students found controlling variables (27.98) very difficult, contradicted earlier findings of Omajuwa (2011) who found controlling variables less difficult; but agrees with the studies by Ango and Sila (1996) and that of Akpokorie (2000) which showed that students found controlling variables very difficult. According to Adeyemi (2000), when students are always exposed to practical lessons, with good quality of teachers and quality of teaching methods, they will obviously find most of these process skills less difficult.

As indicated in Table 4.8 the t value for skills type is .483 not significant at $p = .637$: $p > 0.05$ level of significance; showing that the significant (2-tailed) is greater than 0.05 showing non-significant difference between students' difficulty in basic and integrated skills, hence the null hypothesis was retained. Thus the hypothesis one, no difference between students' difficult in basic and integrated skills was not rejected. The result showed no significant difference in the mean difficulty process skills scores between Chemistry students who experience difficulty in acquiring the basic and integrated science process skills acquisition. This finding may be hinged on the quality of teachers and instructional modes used by the teachers. This finding supports the work of Akpokorie (2000) and Omajuwa (2011) but contradicts the findings of Okebukola (1999) whose study showed that students find all process skills difficult. According to earlier works by Abdullahi (1982) and Ajaja (2009), the reason why students may find all process skills difficult could be due to the persistent use of lecture methods for teaching Chemistry as against the recommended use of laboratory and discovery/inquiry approaches which are student- activity centred.

The analysis showed in Table 4.2 and Fig. 4.2 revealed that the total mean scores of the male students who experienced difficulty in science process skills acquisition was 42.20 while; the mean scores of the female students who experienced difficulty in science process skills acquisition was 40.40. Both males and females experienced insignificant difficulty in process skills acquisition. Also in Table 4.2, the t values for sex for the 15 process skills are .637, .484, .458, .677, .635, .639, .638, .644, .637, .794, .553, .522, .528, .520 and .558 which are greater than; 0.05. This shows that sex have negligible influence on students' difficulty in science process skills acquisition but was tested with hypothesis 2. In Table 4.9, the t-ratio for sex is .731 is not significant at p =.465: p> 0.05 level of significance; showing that the significant (2-tailed) is less than .05. The result showed that there was no significant difference in the mean difficulty process skills scores between male and female Chemistry students. Based on this, hypothesis two was not rejected. The result showed that there was no significant difference in the mean difficulty process skills scores between male and female Chemistry students. Based on this, hypothesis two was not rejected. The findings of this study is in agreement with those of Onwuneme (1992), Akpokorie (2000) and Omajuwa (2011) who found that sex have no influence on students experienced difficulty in science process skills acquisition.

The analysis showed in Table 4.3 and Fig. 4.3 also revealed that the mean scores of the urban students who experienced difficulty in science process skills acquisition was 39.33 while; the mean scores of the rural students who experienced difficulty in science process skills acquisition was 40.40. Table 4.3 showed the t values for school location for the 15 process skills which are .658, .448, .677, .820, .664, .660, .639, .772, .620, .688, .535, .564, .639, .684, .564, .466 and .457 which are greater than 0.05. Both urban and rural students experienced insignificant difficulty in process skills acquisition. This shows that school location have negligible influence on students' difficulty in science process skills acquisition but was tested with hypothesis 3. From Table 4.10, the t-ratio for school location is 3.622 at p=.637; p>0.05; showing that the significant (2-tailed) is greater than .05 hence the null hypothesis Ho3 was not rejected. This showed that there was no significant difference in the mean difficulty of process skills scores between Chemistry students in urban and rural schools. The findings of this study contradicts with the works by Adeyemi (1990) and Agbogoroma (2009); but agrees with the findings of Omajuwa (2011) who found that school location have no influence on students experienced difficulty in science process skills acquisition.

The analysis showed in Table 4.4 and Fig. 4.4 also revealed that the mean scores of the single sex schools students who experienced difficulty in science process skills acquisition was 40.45 while; the mean scores of the mixed schools students who experienced difficulty in science process skills acquisition was 39.03. Table 4.4 showed the t values for school type for the 15 process skills which are .657, .484, .458,.486, .620, .979, 1.000,.953, .668, .666, .553, .586, .555, .526 and .554 which are greater than 0.05. Both single and mixed schools students experienced insignificant difficulty in process skills acquisition. This showed that school type have negligible influence on students' difficulty in science process skills acquisition but was tested with Ho4. As indicated in Table 4.11, the t-ratio for school type is 3.382 at p=.586; p>0.05; showing that the significant (2-tailed) is greater than .05 hence the null hypothesis Ho4 was not rejected. The result therefore showed that there was no significant difference in the mean difficulty process skills scores between Chemistry students in single sex schools and mixed schools. The result therefore showed that school type have no significant difference in the mean difficulty process skills scores between Chemistry students in single sex schools and mixed schools. The findings of this study contradicts with that of Wong et al (2002) but was in agreement with that of Omajuwa (2011) who found that school type have no influence on students experienced difficulty in Science process skills acquisition. This may be due to the fact that since the process skills are activities to be performed by individuals, the school type may not hinder the activities to be carried out when teachers are not sex-biased or are gender friendly. This may have contributed to reasons noted from the works by Malcacova (2007) and Horwood (2010) findings were both girls and boys benefited from single-sex schools.

The analysis showed in Table 4.5 and Fig. 4.5 revealed that the mean scores of students that are from large class sizes that experienced difficulty in acquiring Science process skills were 35.01; while the mean scores of students that are from small class sizes who experienced difficulty in acquiring Science process skills was 50.80. Table 4.5 also showed the t values for class size for the 15 process skills which are .000, .001, .003, .000, .001, .000, .000, .001, .002, .000, .000, .001, .000, .002 and .003 which are less than 0.05. This shows that class size have great influence on students' difficulty in Science process skills acquisition since the mean percent is significant; but was tested with Ho5. As indicated in Table 4.12, the t-ratio for class size is -30.500 at $p=.000$: $p<0.05$; showing that the significant (2-tailed) is less than .05 hence the null hypothesis Ho5 was rejected. This implies that there was a significant difference in the mean difficulty process skills scores between Chemistry students in small-class size and those in large-class size. This result agrees with the works of Okoro (1985) and Adeyela (2000) whose studies revealed that large class size is un-conducive for serious academic work for students and process skills acquisition but; disagrees with the works by Afolabi (2002) and Commeyras (2003) who found no relationship among class size and students' academic performance and process skills acquisition. According to Ajaja (2010) very large class sizes, which exist in schools, have made healthy interactions between students and teachers almost non-existent. Most teachers hardly know their students by their names. The large class size has reduced individual student's attention during practical lesson. Students seeking special attention as a result of lack of clear instruction in practical lessons are hardly attended to. All these culminate in very poor performances of students in test of practical knowledge in final year examinations. But, Brophy (2004) opined that large class size can be handled through proper classroom management and group or cooperative teaching in science labs.

The analysis showed in Table 4.6 and Fig 4.6 revealed that the mean scores of students with positive attitude towards Chemistry who experienced difficulty in acquiring science process skills was 47.0; while the mean scores of students with negative attitude towards Chemistry who experienced difficulty in acquiring Science process skills was 24.88. Table 4.6 also showed the t values for students' attitude for the 15 process skills which are .000, .006, .018, .000, .006, .002, .001, .000, .000, .001, .000, .002, .000, .020 and .011 which are less than 0.05. This shows that students' attitude have great influence on students' difficulty in science process skills acquisition since the mean percent is significant; but was tested with Hypothesis 6. As indicated in Table 4.13, the t-ratio for students' attitude towards chemistry is -3.910 at $p=0.000$; $p<0.05$; showing that the significant (2-tailed) is less than .05 hence the null hypothesis Ho6 was rejected. This implies that there was a significant difference in the mean difficulty process skills scores between Chemistry students with negative attitude and those with positive attitude towards Chemistry. This result agrees with Odunusi (1994) and Yara (2009) who found that students' negative attitude influences their performance in science.

The analysis showed in Table 4.7 and Fig. 4.7 revealed that the mean scores of students in schools with well-equipped laboratories who experienced difficulty in acquiring science process skills was 48.70; while the mean percentage of students in schools with ill-equipped laboratories who experienced difficulty in acquiring Science process skills was 34.93. Table 4.7 also showed the t values for laboratory adequacy for the 15 process skills which are .001, .017, .028, .033, .000, .000, .002, .000, .000, .001, .003, .035, .000, .028 and .026 which are less than 0.05. This shows that laboratory adequacy have great influence on students' difficulty in science process skills acquisition since the mean scores was significant; but was tested with Hypothesis 7. As indicated in Table 4.14, the t-ratio for laboratory adequacy is -19.329 at p=0.000: $p<0.05$; showing that the significant (2-tailed) is less than .05 hence the null hypothesis Ho7 was rejected. This implies that there was a significant difference in the mean difficulty process skills scores between Chemistry students who were taught with well-equipped laboratories and those taught with ill-equipped laboratories. This agrees with the assertions by Burak (2009) who noticed a positive significant in process skills acquisition; and that of Bajah (1980) who found that the correlation between the laboratory adequacy and Science process skills acquisition. Farombi (1998) also opined the effect of using well–equipped laboratories in the teaching and learning of science and other science related disciplines as students tend to understand and recall what they see more than what they hear. Lending credence to this statement, Ogunniyi (1982) said that there is a general consensus among science educators that laboratory occupies a central position in science instruction. Gbamanja (1991) opined that the problem of ill-equipped laboratories can be handled in our secondary schools if only the teachers' can improvise resource materials in science classrooms in order not to hinder the activities to be carried out by students.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

This chapter deals with the summary of the research and major findings, the implications of the study, and conclusion. It also makes some recommendations and suggestions for future research.

Summary of the Research

The West African Examinations Council (WAEC) makes use of practical test/examination to assess students' acquisition of various Chemistry practical skills. In these tests, students are required to carry out certain Chemistry practical activities following some given instructions. The scores of the students' obtained through the marking of their practical works indirectly indicate the levels of Chemistry practical process skills they could demonstrate during the practical examination. This mode of assessment is also adopted by Chemistry teachers who prepare the students for Senior Secondary School Certificate Examination (SSSCE). This mode of assessment influences the teaching methods adopted by teachers. Also, students' learning style is influenced in such a way that they always try to find certain correct responses or answers irrespective of the procedures adopted. It has been proven that the only way the objectives of Chemistry as a subject can be achieved; are for the students to be actively engaged in their Chemistry classrooms.

The main purpose of this study, however, was to identify secondary school Chemistry students' experienced difficulty in process skills acquisition. Seven (7) research questions and seven (7) hypotheses were used for the study. The design adopted for the study was a descriptive survey design. The population of the this study comprised all senior secondary school III (SS III), Chemistry students in the senatorial districts of Adamawa and Taraba States in Nigeria. The sample of the schools used for the study consisted of 36 senior secondary (public) schools while the sample of students consisted of 720 SS III Chemistry students. Twenty Chemistry students were selected from each of the sampled schools. The sample that was used for this study was composed by using multistage random sampling technique.

The research instrument that was used for this study is a test called Science Process Skills Knowledge Test in Chemistry (SPSKTC).The SPSKTC was subjected to both content and face validity by three experts in science education and two in test and measurement. Two Chemistry teachers who have taught this subject for more than eight years also helped in the validation of the instrument. The data obtained was subjected to Kuder Richardson formula 21 to obtain the correlation value. A correlation coefficient of 0.78 was obtained which was considered adequate for this study.

The SPSKTC was administered with the help of the Chemistry teachers (research assistants) and the researcher in the schools. After the administration of the SPSKTC, students' answers were collected and scored using simple means and t-test. The hypotheses were tested with a more descriptive statistics at $t \leq 0.05$ level of significance. The level of difficulty of a particular process skill was determined by the value of means as follows: means scores less than 50 (<50) were classified as Difficult', and means scores equal to or above 50 (≥ 50) as 'Simple'. Each student was scored on each of the science process skills before the individual scores were aggregated to form a composite score for each student. Hypotheses 1-7 were tested with t-test statistic using SPSS 16.0 statistical package.

Research Findings

The results of the analysis showed that:

i. 12 science process skills (80%) were found difficult by students in acquiring which includes: observing, identifying/controlling variables, inferring, predicting, using number relationships, formulating hypotheses, experimenting, communicating, recording, defining operationally, interpreting data, and classifying; with a total mean scores of 39.35out of the 15 science process skills.

ii. There was no significant difference in the mean difficulty process skills scores of

Chemistry students between the basic and integrated science process skills acquisition.

iii. There was no significant difference in the mean difficulty process skills scores between male and female Chemistry students.

iv. There was no significant difference in the mean difficulty process skills scores between Chemistry students in urban and rural schools.

v. There was no significant difference in the mean difficulty process skills scores between Chemistry students in single sex and in mixed schools.

vi. There was a significant difference in the mean difficulty process skills scores between Chemistry students in small-class size and in large-class size.

vii. There was a significant difference in the mean difficulty process skills scores between Chemistry students with negative attitude and those with positive attitude towards Chemistry.

viii. There was a significant difference in the mean difficulty process skills scores between Chemistry students who were taught with well-equipped laboratories and those taught with ill-equipped laboratories.

Conclusion

The following conclusions were made, based on the findings of this research work. This study highlighted the difficulty experienced by Chemistry students in the acquisition of Science process skills. Based on the findings and discussion, it could, therefore, be concluded that majority of the science process skills (80%) with mean scores of 39.35 are found difficult by chemistry students' in acquiring. These process skills include observing, identifying/controlling variables, inferring, predicting, using number relationships, formulating hypotheses, experimenting, communicating, recording, defining operationally, interpreting data, and classifying and this may be as a result of persistence use of lecture method which does not promote active learning in science classrooms. The study also revealed that sex, school location and school type have negligible influence on students' process skills acquisition while large class size, students' negative attitude towards chemistry and laboratory inadequacy have great influence on students science process skills acquisition.

Recommendations

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

1. Laboratories should be equipped and expanded to accommodate and enable teachers to adopt methods that will lead students to have the appropriate skills. Government should be implored to give enough grants to equip laboratories with chemicals and apparatus, and also to provide useful materials and appropriate teaching aids to help reduce the problems of ill-equipped laboratories.
2. The need for training of Chemistry teachers on process skills is also recommended to educate them on student-activity centred methods which promote active learning in science classrooms and acquisition of science process skills.
3. The number of periods per week for Chemistry lessons should be increased to create room for more elaborate laboratory activities with students which will help eradicate students' difficulties in science process skills acquisition.
4. The student-teacher ratio should be drastically reduced to help improve small class sizes such that adequate attention will be paid to students during laboratory exercises.
5. Chemistry teachers should present the process skills in clearer terms, starting from simple too complex to help develop in students' positive attitude towards Chemistry.
6. Teachers should make a "Question Collection on science process skills" and periodically choose a question to initiate a science exploration or activity to reinforce scientific thinking, most especially with students with negative attitude towards chemistry.

7. Teachers should also assess students on the different kinds of science process skills that students can acquire in science classes and the important role they will play in their future so as to arouse students' interest towards chemistry and also reduce students' difficulty in process skills acquisition.

Contributions to Knowledge

This study has contributed the following to knowledge:

i. The study has established that a large proportion of science process skills 80% are found difficult by Chemistry students in acquiring with a total mean scores of 39.35 which includes: observing, identifying/controlling variables, inferring, predicting, using number relationships, formulating hypotheses, experimenting, communicating, recording, defining operationally, interpreting data, and classifying.

ii. The study has reaffirmed that chemistry students' found difficulty in acquiring both the basic and integrated science process skills.

iii. The study has reaffirmed that chemistry students' acquisition of science process skills is negatively affected by large class size; students' negative attitudes towards science and laboratory inadequacy.

The study has also reaffirmed that the influence of sex, school location and school type on chemistry students' acquisition of science process skills are negligible.

Suggestions for Further Studies

Suggestions for further studies are replications of the study in private schools in the three senatorial districts of Adamawa and Taraba states. It is suggested by the researcher that this study should also be carried out more intensively with more samples in all the local governments of the state and other parts of the country.

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APPENDIX I

DEPARTMENT OF SCIENCE EDUCATION
FACULTY OF EDUCATION
DELTA STATE UNIVERSITY, ABRAKA
SCIENCE PROCESS SKILLS KNOWLEDGE TEST IN CHEMISTRY (SPSKTC)

Dear Students,

This test seeks information on the difficulties that students experience while acquiring certain process skills as prescribed by Senior Secondary School Chemistry Curriculum. It seeks to test your knowledge in Science process skills. Please carefully choose only one right answer from options A-D and circle it neatly on the question paper provided.

This test is purely for research purposes as it will help to highlight areas of difficulties in your practical Chemistry so as to find possible solutions to them. Your responses will be treated with the utmost confidentiality they deserve.

Thank you.

SECTION A

Name of School: ________________________

Type of Schools: Boys only ( ) Girls only ( ) Mixed ( )

Sex of Student: Male ( ) Female ( )

Location of Schools: Urban ( ) Rural ( )

No. of students in class: 30 students and below ( ) above 30 students ( )

Attitude towards Chemistry: Positive ( ) Negative ( )

Laboratory adequacy: Well-equipped ( ) Ill-equipped ( )

SECTION B

Science process skills Knowledge Test in Chemistry (SPSKTC)
Instruction: Please circle or underline neatly the correct answer from letters

A-D on your question paper

Observation

1. What is observed when ammonia is tested with concentrated HC1?
   A. Ammonia gives dense white fumes with cone. HC1.
   B. NH_3 gives white precipitate soluble in cone. HC1.
   C. NH_3 evolves reddish brown fumes with cone. HC1
   D. Ammonia gives black fumes with cone. HC1.

2. What would you observe when brown copper (II) trioxonitrate (V) is heat?
   A. It turns to black copper (II) oxide B. It turns to brown copper (II) oxide
   C. It turns to black copper (II) nitrate D. No reaction occurs.
3. State what you would observe when concentrated H_2SO_4 is added to a lump of sugar.
   A. It turns to black B. It turns to brown C. It turns to red D. It turns to green.
4. What would you observe when ammonium chloride is heated in a test tube?
   A. It becomes soluble B. It becomes insoluble
   C. It forms a precipitate D. It sublimes
5. What would you observe when ethylene is bubbled into potassium tetraoxomanganate (VII)?
   A. $KMnO_4$ turns from purple to yellow
   B. $KMnO_4$ turns from purple to orange
   C. $KMnO_4$ turns from purple to green
   D. $KMnO_4$ turns from purple to colourless
6. State the colour you will observe when starch reacts with iodine
   A. Blue-black B. Blue C. Black D. Blue-brown

Classification

7. The following acids are monobasic except
   A. Trioxonitrate (V) acid B. Hydrochloric acid
   C. Ethanioc acid D. Tetraoxosulphate (VI) acid
8. All of these are bases except A. NaOH B. KOH C. Ca $(OH)_2$ D. HNO_3
9. Which one of these is not an acid? A. H_2SO_4 B. HNO_3 C. HCl D. KOH
10. All of these are strong acids except

A. HC1 B. H_2SO_4 C. HNO_3 D. CH_3COOH

11. Which of the following is more suitable for the detection of chlorides?
   A. Forms white precipitate with $AgN0_3$ solutions B. Reacts with H_2SO_4
   C. Forms white precipitate while soluble in dilute NH_3 with $AgN0_3$ solution.
   D. Forms white precipitate with dilute NH_3 solution.

Study the table below and use it to answer question 12.

Element	Melting point (oC)	Physical state of its Oxide	Electrical conductivity of the element
I	39	Solid	Very good
II	112.8	Gas	Nil
III	97.5	Solid	Good

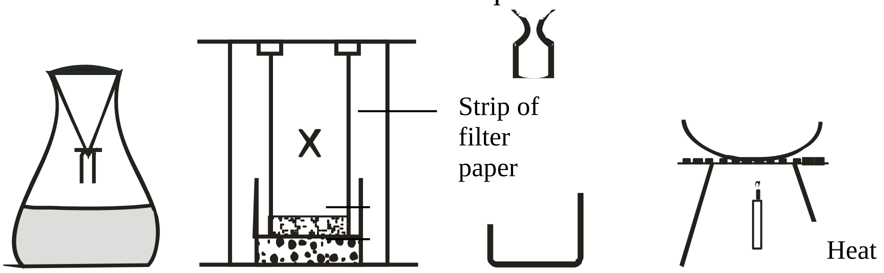
12. Which of the elements in the table above can be classified as metal?

    A. II only B. II and III only C. I and III only D. III only

Measurement

13. Which of the following apparatuses can be used to measure accurately a specific volume of a liquid?
A. Beaker B. Conical flask C. Measuring cylinder D. Pipette
14. What volume of 0.5M H_2SO_4 will exactly neutralize $20cm^3$ of 0.1M NaOH solution?
A. $2.0cm^3$ B. $5.0cm^3$ C. $6.8cm^3$ D. $8.3cm^3$
15. A standard burette used in the laboratory contains of solution?
A. 80 cm^3 B.70 cm^3 C. $50cm^3$ D.50 cm
16. What amount of solution is transferred from the pipette into the conical flask? A. $55cm^3$ B. $45cm^3$ C. $25cm^3$ D. 25cm
17. A student prepares 0.5M solution each of hydrochloric and ethanoic acid and then measured their pH. The result would show that
A. pH values are equal B. HC1 solution has a higher pH
C. Sum of the pH value is 14 D. Ethanoic acid solution has a higher pH

<u>Communication</u>
Use the information below to answer questions 18 -21:



I II III IV

The diagrams labeled I-IV below illustrate different laboratory set-ups used in the separation of mixtures.
18. Name the separation technique illustrated by each diagram in I-1V
A. Filtration, chromatography, use of separating funnel/solvent extraction and evaporation
B. filtration, precipitation, distillation and evaporation
C. filtration, chromatography, distillation and evaporation
D. filtration, chromatography, fractional distillation and evaporation
19. Which of the set-ups is used for concentrating dilute salt solutions for the purpose of crystallization? A. I B. II C. III D. IV
20. Which of the set-ups is used in obtaining clear water from muddy water?
A. I B. II C. III D. IV
21. Mention the set-up you will use to separate a polar solvent from a non- polar solvent. A. I B. II C. III D. IV

<u>Recording</u>
Use the information below to answer questions 22 -23:
In an experiment to standard dilute hydrochloric acid, a student titrated
25.00cm portions of 0.10 mol/dm sodium trioxocarbonate (IV) solution against the acid and recorded his results as follows:

	I	II	III
Final burette reading	26.40	25.50	28
Initial burette reading	0.50	0.80	3.2
Volume of acid used (titre)	25.80	24.70	24.8

Average titre $= \frac{2.80+24.70+24.8}{3} = 25.10$

22. Name a suitable indicator for the titration.
    A. Methyl orange B. Methyl red C. phenolphthalein D. orange
23. Which of these is not an error in the students' recording?
    A. consistent burette reading B. inconsistent burette reading
    C. unit of measurement not stated D. averaging divergent titre values

Use this table to answer questions 24-26 below:

Test	Z	Inference
Filtrate +$NaOH_{(aq)}$ + heat	Gas evolved with choking or pungent smell fumed with conc. HCl or turned red litmus paper blue.	X
Residue + few drops of Iodine solution	Blue-black or dark blue colouration	Y

24. What gas is X? A. NH_3 B. NH_3Cl C. NaOH D. HCl
25. What is present in Y? A. Starch B. protein C. Fats and Oil D. Ammonia
26. What is Z? A. Observation B. Measurement C. Test D. Inference

Using number relationships

A is 0.100 mol dm^{-3} solution of an acid. **B** is a solution of KOH containing 2.8g per $500cm^3$. Volume of pipette is $25cm^3$. [H=1.00, O=16.0, K=39.0]. Use this tabulated reading and the information provided to answer questions 27-30.

	Rough Cm^3	1^{st} Titration(cm3)	2^{nd} Titration(cm3)
Final Burette Readings	24.10	47.00	23.10
Initial Burette Readings	01.10	24.10	00.00
Volume of acid used	23.00	22.90	23.10

27. Calculate the volume of acid used.
    A. $23.00cm^3$ B. $22.90cm^3$ C. $23.10cm^3$ D. 23.00cm
28. Calculate the number of moles of acid in the average titre.
    A. 0.00230 moles B. 0.0230 moles C. 0.230 moles D. 22.90 moles
29. Calculate the number of moles of KOH in the volume of **B** pipette.
    A. 0.00250 moles B. 0.0250 moles C. 0.250 moles D. 2.50 moles
30. Calculate the number of mole ratio of acid to base in the reaction.
    A. 1:1 B. 1:2 C. 2:1 D. 2:2
31. What is the molar mass in g mol- of sodium hydroxide (NaOH)?
    A. 40 B.50 C.60 D. 70

Formulating Hypotheses

Suggest suitable apparatus that could be used to perform each of the following activities in the laboratory in questions 32-34:

32. Storage of dil. Silver trioxonitrate(v)
    A. Big bottle B. Dark brown/amber coloured bottle
    C. Round bottom flask D. Cylinder
33. Heating copper metal
    A. Flame B. Bunsen burner C. lighter D. heater

34. Separation of a mixture of water and kerosene

A. Filter B. separating funnel C. fractioning column D. filter paper

Suggest how the following liquid reagents can be suitably stored in the laboratory in questions 35-36:

35. **X** which fumes in moist air.

A. X is better stored in the fumed cupboard/chamber
B. X is better stored in coloured bottles or dark cupboard
C. X is better stored in cylinders
D. X is better stored in reagent bottles

36. **Y** which is slowly decomposed by sunlight in ordinary reagent bottles.

A. Y is better stored in the fumed cupboard/chamber
B. Y is better stored in coloured bottles or dark cupboard
C. Y is better stored in cylinders
D. Y is better stored in reagent bottles

<u>Prediction</u>

37. Adding dil. HC1 to an aqueous solution of a crystalline salt gives a yellow precipitate and a gas was evolve which turns potassium heptaoxo-dichromate (VI) paper to green. Predict the crystalline salt.

A. $NaHCO_3$ B. $Na_2S_2O_3$ .5H_2O C. Na_2SO_4 D. $ZnSO_4$

38. Predict the salt that will crystallize without water of crystallization.

A. Na_2CO_3 B. NaC1 C. $CuSO_4$ D. $MgSO_4$

39. Addition of an aqueous solution of barium chloride to the aqueous solution of a salt gives white precipitate. The result is likely to be a

A. Trioxonitrate (V) B. Trioxocarbonate (IV) C. Chloride D. Sulphide

40. Elements M, N, O, P and Q form oxides which dissolves in water to give pH as follows:

Oxides of elements M N O P Q
pH of solution 3 5 6 7 9

Which of the elements is likely to be a metal? A. M B. N C. O and P D. Q

<u>Inference</u>

41. Dilute hydrogen chloride acid was added to an aqueous solution of a crystalline salt. A yellow precipitate was formed and a gas was evolved which turns potassium heptaoxodichromate (VI) paper green. The crystalline salt may be ……….

A. $NaHCO_3$ B. $Na_2S_2O_3$ .5H_2O C. Na_2SO_4 D. $ZnSO_4$

42. Carbon (IV) oxide turns lime water milky, but further addition makes the milkness to disappear. This is because

A. Calcium hydrogen trioxocarbonate (IV) is precipitated and then dissolves.
B. Calcium trioxocarbonate (IV) is formed and later dissolves.
C. The solution becomes saturated and carbon (IV) oxide is absorbed.
D. Concentration of the solution occurs with the decomposition of calcium hydroxide.

43. A sample turns lead (ii) ethanoate paper black because of the precipitation of black lead sulphide. The sample is likely to be

A. CO_2 B. H_2S C. HC1 D. H_2SO_4

44. A gas forms dense white fumes of ammonium chloride with aqueous ammonia. The gas is likely to be A. CO_2 B. H_2S C. HC1 D. H_2SO_4

<u>Identifying and Controlling Variables</u>

45. Three solutions contain trioxocarbonate (V), tetraoxosulphate (VI) and sulphide ions. One

reagent that can be used to identify one of them is
A. Sodium hydroxide solution B. Calcium chloride solution
C. Barium chloride solution D. Lead trioxonitrate (V) solution

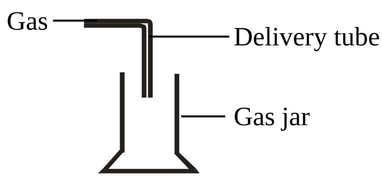
46. A colourless gas P was given off when dilute tetraoxosulphate (VI) acid was added to zinc salt Q. On bubbling the gas through lime water, a white precipitate R was formed. Identify P, Q and R.
A. CO_2, ZnCO3 and$CaCO_3$ B. CO_2, K_2CO_3 and$CaCO_3$
C. CO_2, $ZnSO_4$ and NaOH D. HO_2, $ZnCO_3$ and$CaCO_3$

47. A gas S, with rotten egg smell, was evolved when dil. HCl acid was added to T which is a salt of iron (II). S decolourized acidified potassium teraoxosulphate (VII) solution and a yellow precipitate V was also obtained. Identify S, T and V.
A. S is H_2SO_4, T is FeS and V is Sulphur
B. B. S is H_2SO_4, T is $FeSO_4$ and V is Sulphur
C. S is H_2S, T is FeS and V is Sulphur D. S is H_2SO_4, T is FeS and V is SO_2

48. A soluble chloride X reacted with a liquid Y on heating, to give gas Z which turned moist blue litmus paper red and fumed in moist air. Identify Y and Z.
A. Y is H_2SO_4 and Z is HCl B. Y is H_2SO_4 and Z is NaCl
C. Y is HNO_3 and Z is HCl D. Y is H_2SO_4 and Z is NaCl

49. To a small amount of a compound E in a test tube, dilute HCl was added and heated gently. No effervescence occurred but solid E dissolved to give a blue solution. Identify E.
A. E is CuO_2 B. E is CuO C. E is $CuSO_4$ D. E is Cu_2O

50. Which of the following gases can be controlled by the set-up illustrated below?



A. H_2 B. HCl C. NH_3 D. N_2

Interpreting Data

51. In the titration of acid against base solution, averaging must involve
A. Rough reading B. Concordant reading C. Higher reading
D. One of the titres obtained

52. $Haq^+ + OHaq^- \longrightarrow H_2O_{(l)}$
The above equation represents
A. Hydrolysis B. Hydration C. Neutralization D. esterification

Use the table below to answer questions 53 —55:
Below is a table of four solutions and their pH values

W	X	Y	Z
8	2	7	13

Interpret this data and use it to answer the questions below:
53. Which of them is likely to be most acidic? A.W B. C.Y D.Z
54. Which of them is likely to be most basic? A.W B.X C.Y D.Z
55. Which of them is likely to be neutral? A.W B.X C.Y. D.Z

Making Operational Definitions

56. The reaction represented by equation

$NaOH(aq) + HC1(aq) \longrightarrow NaCl(aq) + H_2O$
A. Is a double decomposition B.Is neutralization
C. Is reversible D. Is usually catalyzed
57. An acid is a substance which in the presence of water produces
A. Salts B. Oxygen C. Effervescence D. Hydroxonium ions
58. ……is a substance which neutralizes an acid to form a salt and water only.
A. An acid B. Litmus C. A base D. Indicator
59. A substance which shows different colours in acidic and basic media is called A. Litmus B. Paper C. Indicator D. Changer

Experimenting

60. Sodium hydroxide is added drop by drop to some hydrochloric acid in a beaker. Which of the following occurs in the beaker?
A. The pH of the solution decreases
B. The concentration of hydrogen ions decreases
C. The concentration of hydrogen ions increases
D. The solution turns pink
61. A molar solution of caustic soda is prepared by dissolving
A. 40g NaOH is l00g of water B. 40g NaOH is l000g of water
C. 2Og NaOH is 500g of water D. 2Og NaOH is l000gofwater
62. Which one of this test can be used to confirm the presence of trioxonitrates (v)?
A. Precipitation B. Evaporation C. Brown ring test D. Dark ring test
63. To a sodium carbonate extract, acidified with dilute HC1 and few drops of barium chloride solution a white precipitate insoluble in excess of dilute HC1 acid was formed. This test confirms which of these anions.
A. C1 B. NO_3 C. SO_4 D. Br
64. To a salt solution was added NaOH solution and a white precipitate insoluble in excess NaOH was formed. This test confirms which of these cations. A. Ca B. Cu C. Fe D. Zn

Manipulating Techniques
65. Filling the burette for titration involves these except
A. Wash with water B. Rinse with acid
C. Eject air bubble D. Read at eye level
66. Which of these is not a technique used when using the burette?
A. Rinse the burette with base to clean it
B. Rinse the burette with distilled water to clean it
C. Clamp the burette vertically and close the tap
D. Pour the solution into the burette via a filter paper.
67. The precautions in using the pipette during acid-base titration involves these except A. Rinse with base B. Avoid air bubbles C. Rinse with acid D. Read at eye level

Building Mental Models
68. What phenomenon does this expression/equation show?
$Na_2CO3.10H_2O \longrightarrow Na_2CO_3.H_2S + 9H_2O$
(Colourless crystals)(White powder)
A. Deliquescence B. Hygroscopic C. Efflorescence D. Hydrolysis

69. Which one of these is a model for calculating acid-base titration?

A. $\frac{C_A V_A}{C_B V_A}=\frac{N_B}{N_A}$ B. $\frac{C_A V_A}{C_B V_B}=\frac{N_B}{N_A}$ C. $\frac{C_A V_A}{C_B V_B}=\frac{N_A}{N_B}$ D. $\frac{C_B V_A}{C_A V_A}=\frac{N_B}{N_A}$

70. Which one of these gives a model for a neutralization reaction?

A. Acid + Base= salt
B. Acid + water= base + salt
C. Acid + base= salt + water
D. Acid + salt = Base + water

APPENDIX II

Calculation of Reliability of the SPSKTC using the Kuder-Richardson 21 (K-R 21)

Item Variance

Item No.	Variance Standard Deviation
1	0.9943
2	0.7124
3	0.8402
4	0.6336
5	0.8472
6	0.8440
7	0.7292
8	0.6985
9	0.9624
10	0.6922
11	0.8665
12	0.9157
13	0.7652
14	0.9661
15	0.5124
Total	11.980

40 subjects were involved in the pre-test using 15 items (process skills). Their scores varied between 35 and 39 with an overall score of 126.42 and; mean of raw scores of the total test of 8.428. The overall variance S=26.303, therefore the overall standard variation was 5.1286

The mean ($\bar{x}$) is the sum of the test scores divided by the number of students taking the exam.

$$\bar{x} = \frac{\sum (x_i)}{n}$$

The variance (σ^2) is the sum of the squares of the deviations of the individual test scores (x_i) from the mean ($\bar{x}$) divided by the number of scores (n). The standard deviation (σ) is the square root of the variance.

$$\sigma^2 = \frac{\sum (x_i - \bar{x})^2}{n}$$

The KR-21 reliability coefficient is calculated from the number of test items (k), the mean (x), and the variance (σ^2).

$$r = \frac{k}{(k-1)}\left(1 - \frac{\bar{x}(k-\bar{x})}{k\sigma^2}\right)$$

Kuder-Richardson 21 (KR -21), r is given by

Where,

r= test reliability

k= number of items on the test

$\bar{x}$=mean of raw scores of the total test

σ^2 = the overall variance for the test

Number of items , k=15

Mean of raw scores, $\bar{x}$ =8.428

Overall variance for test, σ^2 =26.303

r= <u>(15) (1-8.428(15-8.428))</u>

15-1 (15) (26.303)

r= <u>(1.07) (1-55.389)</u>
394.545

r = (1.07) (0.73) =0.78

r = 0.78

Coefficient of reliability of the SPSKTC, r =0.78

APPENDIX III

Distribution of Sample by School Location, School Type and Sex

	Urban schools		Rural schools		
Sex	Mixed sex	Single sex	Mixed sex	Single sex	Total
No. of Schools	13	5	13	5	36
Male	126	60	120	60	366
Female	134	40	140	40	354
Total	260	100	260	100	720

Students' performance in SSCE Chemistry (May/June 2000-2009) showing number and percentage pass at grades 1-6 with average of 38%

Year	Number of pass in Grade 1-6	Percentage (%) pass in Grade 1-6
2000	62442	31.89
2001	66604	30.06
2002	90488	43.42
2003	143839	50.98

2004	105133	38.97
2005	116234	46.76
2006	156388	41.52
2007	134473	32.36
2008	172206	30.11
2009	126199	33.95

Source: WAEC Annual Reports (2000-2009)

APPENDIX IV

Specification of items on Science process skills Knowledge Test in Chemistry (SPSKTC)

	Science process skills	Number of items
1	Observation	6
2	Classification	6
3	Measurement	5
4	Communication	4
5	Recording	5
6	Using number relationships	5
7	Formulating hypothesis	5
8	Prediction	4
9	Inference	4
10	Identifying/Controlling variables	6
11	Interpreting data	5
12	Making operational definitions	4
13	Experimentation	5

14	Manipulating technique	3
15	Building mental models	3
	Total	70

N.B.Skills 1-6 Basic or lower skills; 7-15 Integrated or higher order skills

APPENDIX V

The list of sample schools

Senatorial Districts/LGAs	SCHOOLS

TARABA NORTH	
Ardo-Kola	Government Day Secondary School Sunkani
Jalingo	Government College Jalingo
	Federal Girls Government College Jalingo
	Government Science Secondary School Jalingo
	Federal Government Technical College Jalingo
Karim-lamido	Government Day Secondary School Karim
Lau	Government Day Secondary School Kunini
Zing	Government Day Secondary School Zing
TARABA CENTRAL	
Gassol	Government Day Secondary School Mutum-Biyu
Bali	Government Day Secondary School Suntai
Gashaka	Government Day Secondary School Serti
Sardauna	Government Day Secondary School Gembu
TARABA SOUTH	
Wukari	Marmara Girls Government Day Sec. School Wukari
Takum	Government College Secondary School Takum
Donga	Government Science Secondary School Donga
Ussa	Government Day Secondary School Kpambo
ADAMAWA NORTH	
Hong	Government Science Secondary School Uba
Michika	Government Day Secondary School Michika

	Government Day Secondary School Bazza
Mubi	Government Secondary School Mubi
ADAMAWA CENTRAL	
Yola North	General Murtala Muhammad college, Yola
	Government Girls Secondary School Yola
	Federal Girls Government College Yola
	Concordia college, Yola
Jimeta	Government Day Sec. School Gwadabawa-Jimeta
Girei	Government Girls Secondary School Girei
Fufore	Government Day Secondary School Fufore
	Government Day Secondary School Karlachi
Yola South	Government Day Secondary School Ngurore
	Government Day Secondary School Shagari
	Government Day Secondary School Wuro-Hausa
	Elkanemi college, Yola
ADAMAWA SOUTH	
Toungo	Government Day Secondary School Toungo
Ganye	Government Secondary School Ganye
Mayo-Belwa	Government Secondary School Mayo-Belwa
Guyuk	Government Secondary School Banjiram