COMPARATIVE EFFECTIVENESS OF TWO PROBLEM-SOLVING TEACHING APPROACHES ON SENIOR SECONDARY SCHOOL STUDENTS' ATTITUDE TO AND ACHIEVEMENT IN PRACTICAL CHEMISTRY

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DEDICATION

This work is dedicated to:

My Father, late Chief Joseph Ojo Falana, whose wish was that I would become a medical doctor.

And to

My grand son

Oluwajomiloju Odindiloluwa Afolabi.

ABSTRACT

It has been observed that many secondary school students in Nigerian perform poorly in chemistry. This may be attributed to the teaching methods used by their teachers as well as inadequate provision of practical materials and activities. Very often, students only observe experiments, copy notes and draw diagrams during chemistry lessons. Studies have revealed that students do not actively and effectively take part in practical chemistry exercises and this may be part of the reasons for their poor performance in the subject. This study, therefore examined the extent to which Laboratory Problem-Solving Model (LAPSOM) and Hands-on, Minds-on Problem-Solving Model (HAMPSOM) improved students' attitude to and achievement in practical chemistry. It further determined the moderating effects of chemistry process skills and class size.

A pretest-posttest, control group quasi experimental design with a 3 x 2 x 2 factorial matrix was used. From the eight educational zones in Oyo State, three were randomly selected from Ibadan and Oyo towns. Three Local Government Areas (LGAs) were chosen based on the geographical location from each of the selected zones. Nine public senior secondary schools were randomly chosen from the selected LGAs. Nine intact classes of 359 students participated and were assigned to LAPSOM, HAMPSOM and control groups. Treatment lasted six weeks. The instruments used were: Chemistry Achievement Test (r=0.79), Students' Attitude to Practical Chemistry Scale (r=0.85), Chemistry Process Skills Rating Scale (r=0.78). LAPSOM, HAMPSOM, and Conventional Method. Seven null hypotheses were tested at 0.05 level of significance. Data were analysed using ANCOVA.

There was a significant main effect of the treatments on students' achievement in practical chemistry ($F_{(2,346)}$=13.03, η^2=0.070, R^2=.176). Students exposed to HAMPSOM performed better ($\bar{x}$=20.02) than those in LAPSOM ($\bar{x}$=18.64) and the control group ($\bar{x}$=15.09). There was no significant main effect of the treatments on students' attitude to practical chemistry. Both high and low chemistry process skills had significant effect on students' achievement in practical chemistry ($F_{(1,346)}$=10.15, η^2=0.029, R^2=.176). Students exposed to HAMPSOM with high skill performed best ($\bar{x}$=47.16) followed by those exposed to LAPSOM ($\bar{x}$=40.79) and control ($\bar{x}$= 40.29). Chemistry process skills had no significant effect on students' attitude to practical chemistry. Large and small class sizes had significant effect on students' achievement in practical chemistry ($F_{(1,346)}$=14.54, η^2=0.04, R^2=.176) but students in small class performed better ($\bar{x}$=19.43) than those in large class ($\bar{x}$=16.38). There was no effect on students' attitude to practical chemistry, even though students in large class had better attitude ($\bar{x}$=92.17) than those in small class ($\bar{x}$=90.65). There was a significant interaction effect of treatments and chemistry process skills on students' attitude to practical chemistry ($F_{(2,346)}$=3.31, η^2=0.019, R^2=.032) and also students' achievement in practical chemistry ($F_{(2,346)}$=5.11, η^2=0.029, R^2=.176). The other two-way and three-way interactions had no significant effects on both.

Hands-on and Minds-on problem-solving approach had greater impact than Laboratory problem-solving approach on students' attitude to and achievement in chemistry. Teachers should therefore employ Hands-on and Minds-on problem-solving approach in teaching chemistry.

Key words: Hands-on and Minds-on problem-solving approach, Laboratory problem-solving approach, Students' attitude to and achievement in chemistry, Senior secondary school.

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CERTIFICATION

I certify that this work was carried out by Mrs Ore-ofe Modupe Apara, in the International Centre for Educational Evaluation, Institute of Education, University of Ibadan.

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TABLE OF CONTENTS

CHAPTER FOUR: RESULTS AND DISCUSSION 80

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

FRN:	Federal Republic of Nigeria
FME:	Federal Ministry of Education
WAEC:	West African Examination Council
WASSCE:	West African Senior Secondary Certificate Examination
HAMPSOM:	Hands-on and Minds-on Problem-Solving Model
LAPSOM:	Laboratory Problem-Solving Model
LGAs:	Local Government Areas
SAPCS:	Students' Attitude to Practical Chemistry Scale

CPSRS:	Chemistry Process Skill Rating Scale
CAT:	Chemistry Achievement Test
REPSOM:	Researchers Experimental Problem-Solving Model
NSSP:	Nigerian Secondary School Science Projects
LICL:	Laboratory Inventory Check List
S.S.S:	Senior Secondary Schools
ANCOVA:	Analysis of Covariance

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Problem

Science is probably the oldest course known by human beings, starting from agricultural science which is concerned with food production. This is one of the primary needs of man without which it is impossible for him to survive for a long time. Presently, science and technology have provided modern industries, satellites, computers, internet and have improved communication drastically. Agriculture with biotechnology and genetic engineering have led to increase in food production. Open heart surgery, test tube babies and organ transplant, housing with new building materials, architectural transformation of all kinds of dwellings and working places, public utilities, household gadgets and war weapons. These have caused great changes in the lives, outlook, attitude and habits of all mankind (Mokobia and Okoye, 2011; Adesoji and Olatunbosun, 2008; Uko-Aviomoh, 2003).

Today, the economy and political strength of a nation is judged by how much has been achieved through scientific and technological advancement. Technology cannot thrive if science subjects are not encouraged in schools. Also the future development of any nation in the field of medicine, agriculture and engineering depends on how well science subjects are taught. It has been identified as an essential instrument for providing solution to socio economic problems such as hunger, poverty, unemployment, population explosion and environmental degradation. Science became synonymous with survival and nations looked to science education answers to their problems (Afolabi, Oniyide and Audu 2008; Eke, 2008).

The Oxford Advanced Learner's Dictionary defines science as knowledge about experiments. Science is the study of problems found wherever we live, the finding of answers to specific questions which we formulate as facts, concepts, theories and laws which are recorded and passed on to posterity. Hence science is an interwoven series of concepts, theories, facts and ideas that developed as a result of experimentation. Science education is defined in different ways: It is to improve critical thinking, logical responding and mainly to develop problem-solving abilities of the students (Dogru, 2008). It is concerned with the teaching and learning of science process and principles (FRN, 2004). It also involves training the learner to perform and observe experiment, analyze and interpret data (Eke 2008; Uko-Aviomoh, 2003). The need for indigenous technology and industrial development has made the Federal Government of Nigeria lay more emphasis on science education. The major aim of which is to improve students' ability to reason logically, think critically and at the end solve problems that come their way in the environment (Orimogunje, 2008). Some of the goals of science education according to the National Policy on Education (FRN,

2004) are: To cultivate inquiring, knowing and rational mind for the conduct of a good life. Produce scientists for national development as well as, service studies in technology and the cause of technological development. Provide knowledge and understanding of the complexity of the physical world, the forms and the conduct of life. This means that effective science education does equip the learner with potentials and capabilities for self actualization (Ogunleye, 2008 and Mkpa, 2001).

Chemistry is considered as both basic and applied science. When teaching chemistry, teachers should emphasize both theories and experiments; Chemistry experiments play an important role in teaching and serve as an ideal tool for combining theory and practice. Therefore, chemistry experiments should focus on learning goals and development of students' laboratory skills, scientific reasoning skills, knowledge about experimental design, and comprehensive ability. Many of the studies on students' learning effectiveness tend to focus more on knowledge learning effectiveness, learning retention, and migration on laboratory skills (Shi-Jer, Hui-Chen, Ru-Chu and Kuo-Hung, 2012).

Any nation aspiring to be scientifically and technologically developed must have adequate level of Chemistry education (Eke, 2008). Chemistry can be defined as the science of molecular behaviour. It deals with the composition, properties and uses of matter. It probes into the principles governing the changes that matter undergoes (Ababio, 2011). Chemistry is all around us, it is ubiquitous in everything we do and everywhere we go. For instance, we can see it in our food, appearance, medicine, house objects, electricity, semiconductors, transportation and communication. Besides, Chemistry is central to understanding of biological, environmental, physical, material and medical phenomena. No wonder the developed countries forged ahead by recognising and utilising the relevance of chemistry in their national economy (Ogunleye, 2008).

Research evidences have shown that Chemistry's contribution to quality of life and nation building are worthwhile in all aspects (Festus and Ekpete, 2012). Also at least a credit grade in Chemistry is a pre-requisite for admission into Nigerian Universities for the study of biochemistry, pharmacy and medicine. The Federal Ministry of Education Chemistry curriculum (FME, 2007) has the following objectives;

- To facilitate transition in the use of scientific concepts and techniques acquired in basic science and technology with Chemistry.
- To provide the students with basic knowledge in chemical concepts and principles through efficient selection of content and sequencing.
- To show Chemistry in its interrelationship with other subjects.
- To show Chemistry in its link with industry, everyday life, benefits and hazards and

- Provide a course which is complete for pupils not proceeding to higher education while it is at the same time a reasonably adequate foundation for post secondary Chemistry courses.

The topics in the senior school Chemistry curriculum are arranged into instructional units and sequenced in spiral form with each unit treated in greater detail as the course progresses. Each unit is organised under the following headings: teaching topics, performance objectives, content, activities (teacher and students), teaching and learning materials and evaluation guide. The curriculum stresses the importance of practical activities of the students to ensure that learners are provided with continuous experience in skill of defining problems. Also recognising assumptions, critical thinking, hypothesising, observing, collecting and recording data, testing and evaluating evidence, manipulating variables, generalising and applying generalisations. In line with the current trends in chemical education, the teaching of chemistry focuses on the following broad aims:

- To stress principles and unifying concepts of chemistry without demanding memorization by pupils of a vast amount of factual information and
- To develop skills in investigating problems based on an understanding of practical work (WAEC Syllabus, 2014- 2016).

In implementing the curriculum the document recognised some possible constraints such as ill equipped laboratories, lack of qualified teachers and large classes. Over the years students' performance in the subject has remained persistently low, discouraging and disturbing (Abudu and Gbadamosi, 2014; Ogunleye, 2008; Odubunmi, 2006). Other researchers observed that the teaching of science in Nigerian secondary schools has encouraged memorization of facts, that teachers rely solely on lecture method of teaching at the expense of other methods. As a result, learners were only given the opportunity to listen, record and regurgitate facts whenever necessary. This may be due to lack of understanding of the concepts by the teachers, lack of teaching materials and uncooperative attitudes of the students (Udogu, Ifeakor and Njelita, 2007; Ayogu, 2007; WAEC, 2007 and 2005). Ineffectiveness of science teachers (Berk, 2005). The methods used in teaching science in secondary schools do not help in the acquisition of science process skills by the students (Madu, 2004). Secondary school students often show negative attitude to chemistry (Festus and Ekpete, 2012). Other factors such as poor method of instruction, inadequate exposure to laboratory activities (Nwagbo and Chukelu, 2012; WAEC, 2007), poor knowledge of separation techniques (WAEC, 2005) and lack of problem-solving abilities (WAEC, 2007; 2005). Also failure to read and understand the question before rushing to answer (WAEC, 2007), poor performance in practical chemistry (WAEC, 2012; 2007 and 2003) and poor quantitative skills (WAEC, 2005). Students' gender (Adesoji and Fasuyi, 2001), laboratory inadequacy (Adeyegbe, 2005), school type (Adesoji and Babatunde, 2002), teacher and school environment (Olatunbosun, 2006), all these have led to poor performance of students in West African Senior Secondary Certificate Examination (WASSCE) as shown in Table 1.1.

Table 1.1 STATISTICS OF ENTRIES AND RESULTS FOR MAY/JUNE WASSCE (2000-2012) ON CHEMISTRY

YEAR	TOTAL ENTRY	TOTAL SAT	TOTAL SAT %	A_1-C_6	A_1-C_6 %	D_7 & E_8	D_7 & E_8%	TOTAL FAILED	TOTAL FAILED %
2000	201369	195810	97.24	62442	31.89	52303	26.71	81065	41.40
2001	311606	301740	96.83	109397	36.26	81679	27.07	110664	36.67
2002	291372	287424	98.65	98988	34.42	88580	29.47	99856	36.09
2003	318324	304906	97.84	153839	50.98	79448	24.26	71619	21.84
2004	345078	340774	98.07	128133	38.97	95404	26.83	117237	34.19
2005	338307	327225	98.20	135544	37.35	84267	27.15	107414	35.50
2006	389315	375285	97.93	140263	38.65	89998	29.03	123204	32.32
2007	432230	422681	97.79	194284	45.96	104680	24.76	111322	26.33
2008	428513	418423	97.64	185949	44.44	114697	27.41	110417	26.38
2009	478235	468546	97.97	204725	43.69	114020	24.33	119260	25.45
2010	477573	465643	97.50	236059	50.70	109944	23.61	98165	21.08
2011	575757	565692	98.25	280250	49.54	151627	26.80	129102	22.85
2012	641622	627302	97.77	270570	43.13	192773	30.73	148344	23. 65
2013	649524	639131	98.40	460470	72.05	95030	14.87	61340	9.60
2014	652809	644913	98.79	399062	61.88	142927	22.16	85461	13.25

Source: The West African Examinations Council (WAEC), Test Development Division, Ogba, Lagos.

Table 1.1 reveals that students' performance in chemistry has been very poor, less than 50% of the students who sat for West African Senior Secondary Certificate Examination (WASSCE) from year 2000-2012 had scores within grades A_1-C_6 except in years 2003 and 2010 where the percentages were slightly above 50% (50.98 and 50.70 respectively). There was a great improvement in year 2013 with the highest result, but another drop in percentage in year 2014. In Nigeria students who had scores within A_1-C_6 grade are considered for admission into the tertiary institutions. Therefore the percentage of students who sat for the West African Senior Secondary Certificate Examination (WASSCE) that were considered for admission is less than average (50%)

in year 2000-2012, except in years 2003 and 2010. The highest number of students that were considered for admission was in 2013, but a reduction in percentage of these students in 2014. Failure in other science subjects has been reported by Ogundipe (2004) and Olatoye (2002). Researches show that under achievement and low enrolment in chemistry and other sciences are not limited to Nigeria, this is reported for other countries especially in physics and chemistry (Wetzel (2008); Angrist, Lang and Oreopoules (2007); Stieff and Wilensky 2003).

The poor performance of students has made science educators to focus on how to improve the teaching and learning of chemistry over the years (Adeyegbe, 2005; Osokoya, 2002). They call for a new direction in science teaching being concerned about the state of science education in Nigeria and the need for a radical approach. Adesoji (2008) and Ndioho (2007) suggested that one of the urgent needs in Nigeria is how to improve the teaching and learning of science, that the condition of science teaching and learning in schools is very discouraging, it calls for all stakeholders in education to rise up to this challenge in the interest of national development. The teaching and learning of science need improvement. In their contribution Akinbobola and Afolabi (2010) also suggested that for science teaching to be meaningful and relevant, the nature of science must be adequately reflected. This calls for a shift of emphasis from the traditional content and factual acquisition of scientific knowledge to those that actively involve the learner in learning by doing. With the inauguration of the 6,3,3,4 system a new science curriculum was developed for secondary schools with greater emphasis on laboratory activities and tailored towards an inquiry oriented science (FRN 2004). However this has not solved the problem, population explosion, inadequate qualified teachers coupled with lack of laboratories or a well equipped laboratory and wrong method of instruction have worsened the situation (WAEC, 2007).

Adane and Adams (2011) stressed the importance of practical Chemistry and wrote that students who are given opportunities to work with specimens, manuals and equipments during laboratory work are able to investigate scientific problems which make them understand theories and principles of science concepts better. Also the West African Senior Secondary Certificate Examination (WASSCE) consists of two papers: theory and practical. The practical is 50 marks. This shows that the performance of students in the practical examination is very important since it can affect the overall performance of the students in the examination. It has been reported that the manner in which science subjects are taught in most of Nigerian secondary schools shows that majority of science teachers use the traditional lecture approach. Most science teachers do not encourage students' active participation in the teaching and learning process. There is also inadequate provision for practical activities and those provided are often inappropriate to produce the desired learning effects. Experiments in science subjects are often turned into demonstrations by the teachers for students to observe and to copy notes which involve drawing of diagrams where necessary (Abudu and Gbadamosi, 2014; Agbowuro 2008; Ndioho 2007). In order to try to find solution to these problems because of the importance of practical chemistry, the researcher developed Hands-on and Minds-on Problem-Solving Model (HAMPSOM) and established the extent to which this model and Laboratory Problem-Solving Model (LAPSOM) improved students' attitude to and achievement in practical chemistry. It further determined the moderating effects of chemistry process skills and class size.

In common language, a problem is an unpleasant situation, a difficulty. In Webster's Dictionary a problem is defined as "A question raise for inquiry, consideration, or solution". In a research situation, a problem arises when the researcher is faced with questions to which answers are not readily available, while a scientific problem is a question you do not know the answer to. A problem space is a mental representation of a problem that includes the initial state and the goal state of the problem as well as the intermediate states attained when solving the problem (Taasoobishirazi and Glynn, 2009). Problems occur in a situation where there is some obstacle between the given problem and the goal. The intervening obstacle or barrier or problem space requires planning, thinking and channeling of thought towards finding a solution to the problem.

According to Bilgin (2005), Problem-solving is the highest form of human activity hence the highest form of learning, and has been described as a method of learning. Several terms such as analytical, critical and reflective thinking, scientific method, discovery, inquiry, active learning and process based have been used synonymously with problem-solving. According to Erinosho (2003) scientific inquiry is the key to science learning and children can be helped to develop the required skills. Problem solving has been defined in several ways:

- Problem solving means the application of already acquired knowledge of ordered science process skills (by the solver) to arrive at solution to novel and related chemical problems (Raimi, 2002)
- Problem solving requires overcoming all the impediments in reaching a goal (Bilgin, 2005)
- It is converting an actual current situation (the NOW- state) into a desired future situation (the GOAL-state). Whenever you are thinking creatively and critically about ways to increase the quality of life (or avoid a decrease in quality) you are actively involved in problem solving (Rusbult, 2008)
- It improves students' ability to reason logically, think critically and at the end solve problems that come their way in the environment (Orimogunje 2008)

Problem-solving is one of the most important issues in teaching and learning. The role of problem-solving in science is indispensable. It is an integral part of science. Science itself is a problem-solving subject. It is a subject that revolves around finding one solution or the other to some problems. Problem-solving can and should be the centre of the instruction, also the way it is practiced must change, it should be a part of an active learning of the instructional process. When students know all the relevant facts and principles necessary for the solution of a problem, they may be unable to solve it because they lack any systematic strategy for guiding them to apply such facts and principles (Gok and Silay, 2010). The notion of problem-solving which is sometimes described as a core skill has received much attention in the literature of science education. Unfortunately there is considerable diversity in seeking to describe what problem-solving actually is, ranging from descriptions of analytical procedures to statements like ‘what you do when you don’t know what to do (Rusbult, 2008). For this study problem-solving is the application of acquired knowledge of ordered science process skills (by the solver) to arrive at solution to related problems in order to meet the present scientific and technological trend. There are several methods of studying problem-solving these include; Introspection, behaviourism, simulation, computer, modeling and experiment. This study is on modeling and experiment aspect of problem-solving.

Conceptually, a problem solver (student) needs to possess relevant information and reasons with the relevant information to tackle the problem. In other words, problem-solving involves conscious and systematic application of acquired information and reasoning to overcome an event perceived by an individual as problem. The problem solver is assisted during the experiments with varying degrees of hint, cues and clues. Problem-solving depends on what the solver knows and what he possesses at the time of solving the problem. Students must develop the ability to conduct science investigations using prior knowledge and experiences, along with treating science investigations as problem-solving (Wetzel, 2008). Problem-solving is very important for many subjects. Chemistry is no exception, combining in its problems characteristics of mathematics and physics problems and adding its distinct chemical features (Cardellini, 2006). He further stated that as teachers we believe that working on problems is an effective way to learn, unfortunately, our students usually develop the attitude that arriving at the answer is more important than understanding the solving process. He explained that this is due in part to the way we teach problem-solving, usually when teaching we show them only some stages of the process, neglecting the analysis stage. This is so because as experts we are no longer able to recall the effort we had to expend the first time we tried to solve a problem, since it is now familiar to us. Also that from our presentation, students see a clean, even elegant solution, having little in common with the uncertainty and the fuzzy thinking that they experience when they try to solve a problem themselves. DeHaan, (2009) in his own contribution said that engaging learners in the excitement of science, helping them to discover the value of evidence-based reasoning and higher order cognitive skills, and teaching them to become creative problem solvers have long been goals of science educator reformers. However the means to achieve these goals, especially methods to promote creative thinking in scientific problem-solving, have not become widely known or used. Hence this study used problem-solving strategy.

Attitude according to the Encyclopedia of Education is a predisposition to respond in a certain way to a person, an object, an event, a situation or an idea. An attitude towards something consists of a person's collection of facts about the subject, which may enable her to feel antipathy towards it, and manifest in either acceptance or avoidance of the subject. Oguntade (2000) defined attitude as the effective disposition of a person or group of persons to display an action towards an object based on the belief that such a person or groups of persons has about the object. According to Gonen and Basaran (2008), Ogunkola (2002) and Yoloye (1994) the attitude of a learner towards science would determine the measure of the learners' attractiveness or repulsiveness to science. Rosemund (2006) wrote that attitude implies favourable or unfavourable evaluative reactions towards something, events, programmes, etc exhibited in an individual's beliefs, feelings, emotions or intended behaviours.

Erdermir (2009) indicated that attitudes are seen to be dynamic in nature and under constant change as they interact with behaviour and must be viewed in probabilistic rather than deterministic terms because of the complexity of structure of an attitudinal network. They stressed that attitudes cannot be observed directly, but inferred from what a person says or does, that attitude measurement has become a common part of research into school and schooling throughout the world. That attitude is assumed to have an affective component of how students were seen by peers and themselves. They offered some generalizations about attitudes:

- Students tend to have positive attitude towards school and the subject matter taught at school at all grade level.
- The attitude of students towards school and school subjects tend to become less favourable over their years at school.
- Students tend to like certain subjects e.g. science, sports, reading more than others (e.g. mathematics, writing, agricultural science).

Festus (2007) contended that performance appears generally to be the fundamental goal behind every life struggle, but the positive platform has consequential effects of improving the worth of the students and can only be achieved through acquisition of positive learning attitudes. That the attitude of a student triggers his behavior, and attitudes are antecedents which serve as inputs or stimuli that trigger actions.

The issue of attitude towards chemistry and science in general is also a problem in England, Northern Ireland and Wales. Craker (2006) examined how young people's attitude to science affects their subject choice and achievement. They argued that the introduction of compulsory science education to age 16 in England, Wales and Northern Ireland has not succeeded in changing the level of interest in science. Ishola (2000) attested to the fact that success in problem-solving process depends not only upon the ability to master the conceptual and procedural knowledge but also upon the affective characteristics of the problem-solver (student). That those with positive attitude towards instruction and subject content are more likely to perform better than students with negative attitude. Several studies have been reported in literature on the relationship between attitude toward problem-solving and students' performance. In a study on students' attempt to solve chemical problems, Frazer and Sleet cited in Sule (2000) after analyzing seventy six sixth form students' solutions to the problems given, selected twenty two unsuccessful students for further in depth analysis. The researchers found that seventy six percent of the unsuccessful students have negative attitude towards problem-solving. Norman and Salleh (2006) indicated that students' attitude and interest could play a substantial role among pupils studying science.

Studies show that most of the secondary school students often show negative attitude to chemistry which is associated with the poor performance in the subject in West African Senior Secondary Certificate Examination (WASSCE) (Festus and Ekpete, 2012; Adesoji,2008). In his own contribution Akubuiro (2004), asserted that students' attitude towards science subjects is positively related to their performance in these subjects, that attitude contributed substantially more than other variables in predicting achievement. A number of other studies on the relationship between students' attitude and learning outcome in science show that science educators have not reached a consensus on the relationship between the two variables. Adesoji (2008); Goner and Basaran (2008) stated that conclusions from researches show that in order to increase the level of attitude and success in science education, new teaching methods and technology need to be implemented in science education. It is on these reports that the researcher developed a model known as Hands-on and Minds-on Problem-Solving Model (HAMPSOM) combining both theoretical and practical aspect of chemistry, which does not exist in literature but separate theoretical and separate practical models. She compared the effect(s) of this model with Laboratory Problem-Solving Model using the instructional guides on students' attitude to and achievement in practical chemistry. She assessed the level of chemistry process skills possessed by the students and studied the effect of class size. Achievement is defined as 'a thing that somebody has done successfully, especially using their own effort and skill' (Oxford Advanced Learner's Dictionary pg 11). Gok and Silay (2010) discovered that when problem-solving achievement of the students increases, the motivation and attitude of the students probably increases. Gonen and Basaran (2008) reported that students' positive attitude towards science probably correlate with their achievement in science.

Apart from the possible influence of treatments (independent variables) on students' attitude to and achievement in practical chemistry (dependent variables), factors such as possession of chemistry process skills and class size were considered in this study. In literature not much work was seen on chemistry process skills and the reports from the few researchers such as: poor quantitative skills, poor exposure to laboratory activities, poor performance in practical chemistry (Nwagbo and Chukelu, 2012; WAEC, 2007 and 2005). These are some of the reasons why this study looked at possession of chemistry process skills. Since the main focus of this study is to help students to acquire skills to arrive at solution to problems that come their way in the environment, also to meet the present scientific and technological trend. Class size as reported in literature was identified as one of the factors probably responsible for the problems discussed above and also one of the possible constraints in implementing the senior secondary chemistry curriculum. Therefore the study looked at class size as one of the moderating variables.

Performing experiments and practical are integral part of chemistry lessons. Research studies have shown that students may achieve greatly when the teaching and learning of science occur in an environment where students are allowed to carry out investigations, not only in the aspect of understanding scientific concepts but also in acquiring scientific skills (Nwagbo and Chukelu, 2012). Adane and Adams (2011) also discovered that students who are given opportunities to work with specimens, manuals and equipments during laboratory work are able to investigate scientific problems which make them understand theories and principles of science concepts better. Hands-on science education experiences may have lasting and personal effects on students (Hudson, 2007). Most secondary school teachers often pay little attention to practical work and laboratory activities as a very good way of promoting the learning of chemistry and also acquisition of appropriate skills (Millar, 2004). It has been observed that when practical is taught, teachers often neglect the teaching of the necessary practical skills (Agbowuro, 2008).

Process of science refers to the practices used in science to uncover knowledge and interpret meaning of those theories (Carpi and Egger, 2009). While scientific method is a way to ask and answer scientific questions by carrying out experiments and making observations. The underlying skills and premises which govern the scientific method are referred to as science process skills (referred to as chemistry process skills in this study) (Geek, 2012). Science process skills are a set of broadly transferable abilities and potentials appropriate to science discipline and reflective of true behaviour of scientists (Okeke, Akusola and Okafor, 2004). Wetzel (2008) discovered that problem-solving is the essence of scientific investigations, that it relies heavily on the effective use of the science process skills possessed by students to complete an investigation. That the science process skills are the foundation of problem-solving in science therefore they are also problem-solving skills. These skills are separated into two categories namely basic and integrated. The basic science process skills are: Observing, Classifying, Measuring, Communicating, Inferring and predicting. The integrated science process skills include: Experimenting and Interpreting data. There is a hierarchical relationship between the two broad skills the acquisition of basic skills is a pre-requisite for the acquisition of integrated skills. This study will concentrate on most of basic skills such as measuring, observing, inferring, predicting and the integrated skills such as experimenting and interpreting data.

Problem-solving skill is one of the important goals of chemistry education any chemistry curriculum sets this skill as a criterion for any planned instruction to reach (Bilgin, 2005). In their own contribution Mahalingam, Schaefer and Morlino (2008) wrote that chemistry as a discipline involves problem-solving. They went further that lack of the requisite problem-solving skills in chemistry is an obstruction to doing well in the course. They added that the passive nature of a traditional question and answer recitation does not provide an adequate environment to develop these skills. Hence this study examined the extent to which Laboratory Problem-Solving Model (LAPSOM) by Onwioduokit (1989) and Hands-on and Minds-on Problem-Solving Model (HAMPSOM) developed by the researcher using the instructional guides, involved the students in problem-solving through their influence on students' attitude to and achievement in practical chemistry, compared the effects of the two model approaches through their interactions with the variables, assessed the level of possession of chemistry process skills by the students and the effects of class size.

Step by step procedures of problem-solving are called scientific methods. Solving any problem scientifically involves several steps, which are constructed in form of model. Model involves the use of diagrams, concepts maps, graphs, pictures, physical models and other means to explain an investigation's findings (Wetzel, 2008). Several researchers in problem-solving process developed different theoretical context models which are based on step by step approach such as Klavir and Gorodetsky (2009) and Ishola (2000). Some researchers realising the importance of practical in the science classes developed problem solving models in practical (Laboratory) contexts these are Problem-Solving Model with eight steps by Wetzel (2008); Inquiry Based

Framework for Practical Problem-Solving Model with seven steps by Ige (2003); Laboratory Problem-Solving Model (LAPSOM) with five steps by Onwioduokit (1989).

Cardellini (2006) discovered that many models have been used in teaching but still the performance of the students is still low. Hence the reason for this study which involves the development of a combined theoretical and practical model by the researcher which is Hands-on and Minds-on Problem Solving Model (HAMPSOM), using problem-solving models by Selvaratnam and Frazer (1982) and Ikitde (1994) because of the unique nature of these models, incorporating intensive theoretical background and teacher guided discovery learning. The effectiveness of this model was compared with that of Laboratory Problem Solving Model (LAPSOM) developed by Onwioduokit (1989), using the instructional guides for the two models. LAPSOM has its root in the science approach models and in the philosophy of instrumentalism derived from John Dewey's pragmatic view. It facilitates student's development of skills in practical (Figure 2.2, pg 40). It is in two parts. The first part shows a general approach for solving practical problems, consists of five procedural stages and eight action steps. The reversible nature of the procedure ensures cognitive and process flexibilities which are required at each stage for arriving at the problem objective. The second part is concerned with how students are taught to use the systematic approach. This is the Instructional Guide.

Hands-on and Minds-on Problem Solving Model (HAMPSOM) developed by the researcher (Figure 2.3, pg 45), is sequential, hierarchical and reversible. It is useful for acquisition of knowledge and the development of laboratory skills in practical and fosters experimental proficiency of students, where they have to raise questions about what to do with the apparatus and materials presented to them. It is in two parts, the first part is the approach for teaching the skills with five procedural stages and eleven action steps. The second part is concerned with how teachers and students use the systematic approach in problem-solving which is the Instructional Guide. An advantage of this model is that it can also be used for non experimental studies. This involves moving from stage 1B (Acquiring related theory) to stage 2A (Recalling theory) to stage 3B (Recording Data).

Averett and Mclennan, (2011) and Ogundipe (2004), discovered another problem which is over population of students in the classrooms. This is as a result of population explosion arising from free education policy of Government in 1979. That the effect of this is that some classes contained as many as sixty eight (68) students who were therefore denied the individual or group attention that would have been beneficial to them. That a small group is described as that having few teachers with small pools of talent, often with limited range of subjects and characteristically finding it hard to justify costly investments on libraries, their pupils lack competition and interact with relatively few peers as they get stuck with same teachers for an entire school career. They explained further that large class size, on the other hand, is not conducive for serious academic work students may suffer discipline problems as teachers cannot get to know their students easily. Teachers may not find it easy to stream students according to their ability, while commitment to work may stand the test of time.

The National Policy on Education (FRN, 2004) stipulates that the minimum number of students in a class in the secondary school is forty (40). This formed the basis for the classification of class size in this study which is forty (40) students and below constitute small class size, while forty one (41) students and above constitute large class size.

1.2 Statement of the Problem

Learning is an active, constructive, cummulative and goal-oriented process that involves problem-solving. Researches show that students need problem-solving skills to solve problems successfully. The extent to which the students are involved in problem-solving and the possession of problem-solving skills are necessary for the students to perform well in the examinations and to meet the scientific and technological trend in Nigeria.

Researches show that the majority of science teachers use the traditional lecture method which does not encourage students' active participation in the teaching-learning processes. There is also inadequate provision for practical activities. Experiments are often turned into demonstrations for students to observe, to copy notes and draw diagrams during chemistry lessons. These and other factors have led to poor performance of students in chemistry in WASSCE.

In view of the above there is need to improve the teaching and learning of chemistry in order to improve students' problem-solving attitude and achievement for better performance in WASSCE. In an effort to seek for solution to this problem, the researcher developed a model Hands-on and Minds-on Problem-Solving Model (HAMPSOM) which combines both theoretical and practical aspects of science as opposed to the separate theoretical and practical models found in literature, incorporating intensive theoretical background and teacher guided discovery learning.

This study therefore examined the extent to which the models (HAMPSOM) and Laboratory Problem-Solving Model (LAPSOM) using the instructional guides improved students' attitude to and achievement in practical chemistry. It further determined the moderating effects of level of possession of chemistry process skills by the students and class size.

1.3 Hypotheses

Ho_1: There is no significant main effect of treatments on students'

- a attitude to practical chemistry.
- b achievement in practical chemistry.

Ho_2: There is no significant main effect of level of possession of chemistry process skills on students'

- a attitude to practical chemistry.
- b achievement in practical chemistry.

Ho_3: There is no significant main effect of class size on students'

- a attitude to practical chemistry.
- b achievement in practical chemistry.

Ho_4: There is no significant interaction effect of treatments and level of possession of chemistry process skills on students'

- a attitude to practical chemistry.
- b achievement in practical chemistry.

Ho_5: There is no significant interaction effect of treatments and class size on students'

- a attitude to practical chemistry.
- b achievement in practical chemistry.

Ho_6: There is no significant interaction effect of level of possession of chemistry process skills and class size on students'

- a attitude to practical chemistry.
- b achievement in practical chemistry.

Ho_7: There is no significant interaction effect of treatments, level of possession of chemistry process skills and class size on students'

- a attitude to practical chemistry.
- b achievement in practical chemistry.

1.4 Scope of the Study

This study involved practical oriented teaching with experiments incorporating intensive theoretical background and teacher guided discovery learning using two problem-solving models (LAPSOM and HAMPSOM) and control instructional guides. From the eight educational zones in Oyo state, three were randomly selected from Ibadan and Oyo towns these are Ibadan city, Ibadan less city and Oyo. Three Local Government Areas (LGAs) were chosen from the selected zones making nine LGAs namely Ibadan North, Ibadan North West, Ibadan South West, Akinyele, Egbeda, Oluyole, Atiba, Afijio and Oyo East. Nine public senior secondary schools were randomly chosen from the selected LGAs. Nine intact classes of 359 chemistry students of Senior Secondary two (S.S 2) participated in the study. The topics investigated are:

- Nature of matter: physical and chemical changes, elements, compounds, mixtures and determination of the empirical formula of magnesium oxide.
- Separation techniques: Sublimation, Filtration, Evaporation, Separating funnel method.
- Volumetric analysis (Quantitative analysis).

The main and interaction effects of treatment, level of possession of chemistry process skills and class size on the dependent variables were investigated.

1.5 Significance of the Study

Teaching of problem-solving skills has often been a neglected aspect of chemistry instruction by teachers at the secondary school level. These have led to poor acquisition of problem-solving skills through performance of practical and experiments by the students as well as poor handling of problems.

It is therefore hoped that, the result of the study could provide information on the effect of treatments on students' exposure and possession of chemistry process skills to solve problems in chemistry. It may confirm the effectiveness or otherwise of the use of practical oriented teaching approach of problem-solving in the teaching and learning of chemistry. It could show which of the two models used is more effective on students' attitude to and achievement in practical chemistry.

Furthermore, the result of this study in all possible interaction of the independent variables could provide the empirical basis for planning and executing a more effective technique of teaching chemistry aimed at improving students' performance in the subject in the cognitive, psychomotor and affective domain. It is hoped that it may consequently have a lot of implications for the aspect of chemistry education dealing with curriculum planning, teacher training as well as classroom practices.

Finally it could add to the pool of knowledge in the area of improving the teaching and learning of chemistry at the Senior Secondary School level through the use of HAMPSOM, thereby improving the performance of the students in WASSCE. This may increase the number of students that will enroll for the sciences in higher institutions of learning. This is beneficial to the society because there could be increased manpower in chemistry related fields, leading to improved health, agriculture and other services.

1.6 Definition of Terms.

Operational Definition of Terms

Problem Solving Model: This is a framework which shows the different stages a learner is expected to go through, from the problem state to solution state.

Laboratory Problem Solving Model (LAPSOM): This is a model which consists of five procedural stages and eight action steps. It involves students carrying out activities without the guidance of the teacher. **The stages are: Stage 1:** Recognize the problem, **Stage 2A:** Reviewing information. **Stage 2B:** Predict tentatively. **Stage 2C:** Draw up table for data. **Stage 3A:** Conducting experiment. **Stage 3B:** Predicting from data. **Stage 4A:** Analyze the data. **Stage 5:** Reviewing.

Hands-on: This is used to describe the fact that students need to perform activities that create opportunities for them to interact with the apparatus (manipulation).

Minds-on: This involves presenting students with challenging situations where they have to raise questions about what to do with the apparatus and materials presented to them.

Hands-on and Minds-on Problem Solving Model (HAMPSOM): This is a model which consists of five procedural stages and eleven action steps. It involves students carrying out activities and to think critically about what they are doing and ask questions which the teacher provides answers to. The stages are: **Stage 1A:** Problem Perception **Stage 1B:** Acquiring Related Theory. **Stage 1C:** Planning Experiment. **Stage 2A:** Recalling Theory and Making Tables. **Stage 2B:** Performing Experiment. **Stage 3A:** Observation. **Stage 3B:** Collecting and Recording Data. **Stage 4A:** Analysing Result. **Stage 4B:** Interpreting, Predicting data and drawing conclusion. **Stages 5A:** Evaluation of results and methods. **Stage 5B:** Consolidating Knowledge Gained and Change in Technique**.** They may change method or quantities to observe the outcome.

Problem-Solving Instructional Guide: This is the actual method of instruction which the teacher and the students undergo during the administration of the treatments and control. For this study, Laboratory Problem-Solving Model (LAPSOM), Hands-on and Minds-on Problem-Solving Model (HAMPSOM) and Conventional Method (control) instructional guides were used.

Science Process Skills referred to as **Chemistry Process Skills** in this study**:** These are the various skills the learners acquire during the administration of the treatments and control. These skills are separated into two categories namely, basic and integrated. The basic science process skills are: Observing, Classifying, Measuring, Communicating, Inferring and predicting. The integrated science process skills include: Experimenting and Interpreting data.

Level of possession of Chemistry Process Skills: These are the level at which the students acquire these different skills. They are measured using Chemistry Process Skill Rating Scale (CPSRS) pre and post.

Chemistry Achievement: This is the students' scores in the pretest and posttest Chemistry Achievement Test (CAT) from Nature of matter, Separation techniques, Volumetric analysis (Quantitative analysis).

Students' Attitude to Practical Chemistry: This is the students' scores derived from Students' Attitude to Practical Chemistry Scale (SAPCS).

Learning Outcomes: These refer to the scores obtained by students in the chemistry achievement test and Students' Attitude to Practical Chemistry Scale after their exposure to the treatments and the conventional method.

Class Size: This is the number of students in the class

Small Class size: This is a class with a maximum of 40 students.

Large Class Size: This is a class with more than 40 students.

Conceptual Definition of Terms

Problem-Solving: This is the application of acquired knowledge of ordered science process skills by the problem-solver (student) to arrive at solution to related problems in order to meet the present scientific and technological trend.

Introspection: This is the careful examination of one's thought, feeling and reasons for behaving in a particular manner.

Simulation: A situation in which a particular set of conditions is created artificially in order to study or experience processes that could exist in reality.

Behaviourism: The theory that all human behaviour is learnt by adapting to outside conditions and that learning is not influenced by thoughts or feelings.

Modeling: The work of making a simple description of a system or a process that can be used to explain it.

Practical: A lesson or an examination in science or technology in which students have to do or make things not just read or write about them.

CHAPTER TWO

2.0 LITERATURE REVIEW

The review of related literature is highlighted in this chapter as follows:

2.1 Theoretical Background
2.2 Conceptual Framework
2.3 Teaching Effectiveness in Science and Practical Chemistry
2.4 Problem-Solving as an Inquiry-Based Instructional Strategy
2.5 Problem-Solving Models
2.6 Students' Attitude to Science and Practical Chemistry
2.7 Achievement in Science and Practical Chemistry
2.8 Chemistry Process Skills and Students' Attitude to Science and Practical Chemistry
2 9 Chemistry Process Skills and Achievement in Science and Practical Chemistry
2.10 Class Size and Students' Attitude to Science and Practical Chemistry
2.11 Class Size and Achievement in Science and Practical Chemistry
2.12 Appraisal of literature reviewed

2.1 Theoretical Background

The present study is conceived on the basis of some psychological learning theories that are considered relevant to the teaching and learning of science, and which are connected to problem-solving acquisition of practical skills and learning of science practical in general. Reforms movement in Science Education emphasize the role of the learner as self directed, critically reflective, creatively involved in theory building, testing and cooperatively engaged with others in dialogue and discovery. This has been recommended as a way of enhancing learning in science by way of making its teaching more real and in line with the spirit of "what scientists do" (Cimer, 2007; Hudson, 2007). This is because teaching of science through experiments and practical activities enable learners' to gain in depth knowledge of what is being taught. This line of thought conforms with the practical activity and experimental aspects of this study; which include enhancing science learning through hand- on activities. Experiments and practical activities involve such skills as manipulation of laboratory equipment, observing, measuring, classifying, inferring, hypothesising. It also requires the application of the knowledge of learned concepts, laws and theories to real concrete situations. The theories of Piaget and Gagne would provide the theoretical framework for this study.

Piaget's Theory of Human Cognitive Development.

Piaget (1978)'s, theory of human developmental psychology is of relevance to this study as it provides explanation for the development of students' mental structures which are capable of influencing learning and understanding. He believed that human development has four stages, each one of the stages building on the previous one. The ability of a child to use symbols and think in an abstract manner increases with each subsequent stage until he is able to manipulate abstract concepts. He emphasized that a child is most likely to attain full intellectual development at the formal operational stage during early adolescence. At this stage, the child's thought process becomes orderly and reasonably well integrated. He is able to understand and transfer understanding from one situation to another. His orientation to problem solving becomes distinct. The child is able to deal with a problem by gathering all relevant information and then making all possible combinations of the variables that can be employed in solving problems through the processes which form the building block of problem-solving model.

The learner is trained on how to solve problems by proceeding in a logical step by step sequence without skipping any step in the learning process. This means that whatever new concepts that is presented to the learner, there must have been concepts that are pre-requisites to that new knowledge in order for the learner to solve existing problem. Piaget believed that the knowledge of a particular capability would be a pre-requisite for a much higher capability for instance some concepts such as mole concept are pre-requisites for solving problems in volumetric analysis. That learning is through activity and experience, which could be used to explain the use of laboratory teaching strategy and experimental demonstration in this study, because the learners' concept of quantity, time, space, conservation and reversibility have developed, logical processes such as observing, describing, classifying and measuring real objects can take place. The application of this to practical teaching is necessary in that students should be assisted and helped to explore and interact with their environment as they are observing things around them. It is therefore necessary to allow students to interact with concrete materials so that the skills involved in measuring, observing, manipulating and in handling concrete materials can be developed. The knowledge of Piaget's theory enables teachers assess the level of students' cognitive development and helps them formulate teaching strategies that are most appropriate in dealing with the students' problem-solving difficulties and to match curriculum with the abilities of the learners. The knowledge of this theory tremendously assisted the researcher in the course of this study.

Gagne’s Theory of Hierarchical Task and Instructional Strategy

The problem-solving instructional strategies used for this study are based on Gagne (1977) theory of hierarchical task. His theory assumes that any piece of knowledge can be acquired by students who possess certain pre- requisite knowledge. According to this theory, prior knowledge determines what further learning that may take place. He believes that meaningfulness of instructional materials can be achieved through movement from concrete materials to abstract that is, learning should be sequentially structured by the teacher. He advocated for the breaking of task into a sequence of steps which are arranged in hierarchy. The theory of hierarchical learning is adopted in problem solving where a learner progresses from one step to another following the steps and strategies in the problem-solving model in which the success in one step determines the success of the next.

The problem-solving instructional guide drawn from the two models used in this study were based on Gagne’s theory of instructional strategy which enunciated the elements of the components guiding the development of an instructional strategy. These elements guided the choice of steps built into the instructional guides. The instructional strategy based on Gagne’s theory begins with the teacher asking questions/ problem statements as in step 1A (Recognition of problem). This is followed by bits and pieces of knowledge or operations needed by the students to carry out activities that will enable them to acquire the desired body of knowledge to solve the problem, which are steps 1B, 1C and 2A (Gathering and processing information). The related theory which is the information has to be recalled before solution is arrived at. This is followed by task analysis as in steps 2B, 3 and 4 (Experimentation and Analysis of results). Evaluation follows when the learning hierarchy is completed which could be in form of diagnostic test (step 5).

Lastly the need for pre-requisite concepts in order to be able to understand the higher concepts in a learning hierarchy was emphasized by the two theorists.

2.2 Conceptual Framework

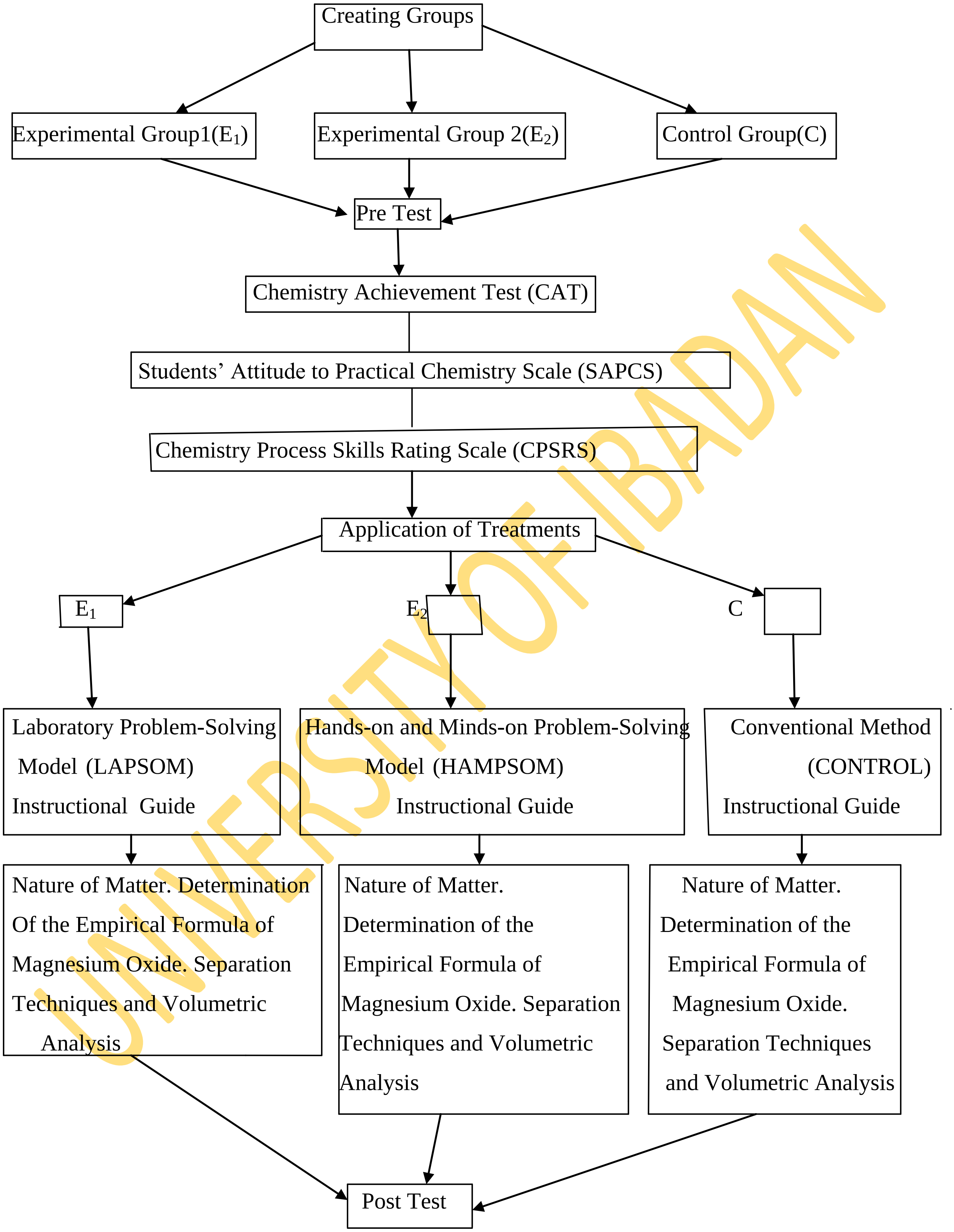

Figure 2.1: Conceptual Framework

2.3 Teaching Effectiveness in Science and Practical Chemistry

Teaching effectiveness is the extent to which students' performance improve after a period of instruction in a manner consistent with the goals of instruction. This means that teachers are said to be effective when their teaching can lead to students' learning. It is therefore defined as a purposeful activity carried out by someone with a specialized knowledge in a skillful way to enhance the cognitive, affective and psychomotor development of a person or group of persons (Abudu and Gbadamosi, 2014; Olatoye ,2002). This means that it can be referred to as the ability of teachers to assist students achieve the desired educational outcomes through various approaches. The difficulties in defining effective science teaching are embedded in the numerous characteristics and roles of the classroom teacher. It is generally accepted by researchers and educators for example Loughran, Mulhall, and Berry, (2004); Hattie, (2003) that effective science teaching requires an understanding of the subject matter, which needs to be taught in engaging ways. There is also empirical research and scholarly debate about what constitutes effective learning. Some of these theories include authentic learning (Herrington and Oliver, 2000), constructivism and social cognitive theory of learning (Vygotsky and Bandura, cited by Hudson, 2007). A teacher's unpretentious, caring nature can motivate students to work to their fullest potential (Alder, 2002; Easton, 2002).

Cimer (2007) summarised some of the main principles of effective teaching in science as follows:

- dealing with students' existing ideas and conceptions,
- encouraging students to apply new concepts or skills into different contexts,
- encouraging students' participation in lessons,
- encouraging students' inquiry and
- offering continuous assessment and providing corrective feedback,

He discussed these principles in terms of their contribution to effective teaching, and to students' learning in science.

Dealing with Students' Existing Ideas and Conceptions

Determining students' existing ideas and conceptions has been recognised as an important variable in science teaching and a necessary part of teaching strategies. He discussed the role of students' existing ideas and conceptions in terms of learning and teaching science and then, described how to identify these ideas and conceptions. Finally, he presented ways to change these ideas and conceptions in order to help students learn science meaningfully.

Tytler (2002); Hipkins, Bolstad, Baker, Jones, Barker, Bell, Coll, Cooper, Forret, France, Haigh, Harlow and Taylor (2002) argued that teaching science is effective when students' existing ideas, values and beliefs, which they bring to a lesson, are elicited, addressed and linked to their classroom experiences at the beginning of a teaching programme. That there is a common belief that students do not arrive in the classroom as empty vessels into which new ideas can be poured by teachers. They can have prior ideas and conceptions about the events and phenomena in the world around them, which might well be different from those intended by the teacher and scientific community. That meaningful learning occurs as students consciously and explicitly link their new knowledge to existing knowledge structure. This implies that effective instructional approaches have to be based on what is already known by the learner. Therefore, the diagnosis of learners' pre-existing knowledge is important for teachers in order to plan subsequent teaching activities and help students link the new material to what they already know. Also determining students' existing ideas and conceptions in science may increase students' awareness of them, which is necessary for meaningful learning. When students become aware of their previously tacit ideas, they have a chance to compare them with scientific ones and change if necessary. In addition, determining students' pre-existing ideas and conceptions also help teachers confront any alternative ideas or misconceptions students may have at an early stage in the learning process so that these do not hinder students' learning (Cimer, 2007).

Through determining students' existing conceptions, teachers can develop appropriate instructional strategies that move these unscientific ideas and conceptions towards scientific ones (Hipkins *et al*, 2002). However, it is noteworthy that there is research evidence that students' alternative conceptions are difficult to shift, and can offer a serious barrier to effective teaching (Tytler, 2002). Hipkins *et al* (2002) indicated that when teachers take into account and build on students' existing ideas, experiences, and values, science education can become more inclusive for students from diverse cultures, girls and boys, students with special needs and special abilities. They explained that in order to determine students' existing ideas and conceptions, the literature reported a wide range of instructional methods and activities that teachers can use, such as reviewing previous work and stating goals, question-and-answer, group discussions, brainstorming and debating ideas, providing examples, and conducting experiments. In addition, students also need positive supportive learning environment where they feel comfortable and confident enough to disclose their existing ideas and thoughts (Bell and Cowie, 2001).

Teaching strategies shape the learning environment. As part of the lesson design, an effective teacher selects a particular teaching strategy or set of strategies to engage students in learning. There are teaching strategies that can be transferred from one subject to the next. There are also strategies that are more specific to a subject area. Generic teaching strategies include models for learning, and specific science teaching strategies. All these strategies can be used to enhance the teaching and learning of science, and a teacher's affective domain appears towards the top of the list. When considering teaching strategies, experienced teachers understand the powerful influence of the teacher's affective domain. This domain includes the teacher's emotions, motivations, attitudes, and values. A teacher who displays enthusiasm for teaching science demonstrates positive emotions about science, which can influence students' attitudes. "I have noted time and time again how the teacher's affective domain can inspire or dampen students' interests in a subject, and I've also noticed this with my own children. For example, my son gained a love of science in Year 7, which he attributed to the highly-motivated teacher; yet in Year 8 he "hated" science, which he also linked to the teacher's attitude". The teacher's affective domain can make the difference! (Hudson, 2007). Teachers generally enter the profession to "make a difference" to students' lives (Neal, McCray and Webb-Johnson, 2001). Knobloch (2003) stated that effective teachers who make a difference in the lives of their students are likely to be affectively motivated and caring teachers.

Teaching methods such as presenting information to students directly from textbooks, providing demonstrations and activities without helping students to focus on the patterns that are similar in the activities, or providing a discovery-oriented lesson without specifically relating it to prior knowledge, on the other hand, may not be successful in helping students to reveal their existing ideas. Briefly reviewing previous work at the start of a lesson by explicitly stating the goals of the current lesson activates students' existing ideas and conceptions regarding the new topic and helps retrieve previous learning. This helps students to be prepared for understanding the new material. The question-and-answer method is one of the most common methods used by teachers for this purpose (Amos, 2002). Questions, especially open-ended ones, can stimulate students to expose their informal and perhaps distorted preconceptions developed through their everyday experiences to facilitate their recalling ideas from their long-term memory (Cimer, 2007).

Sunal and Sunal (2002) emphasised that the important point is to help students retrieve as many related experiences, ideas or skills from their long-term memory as possible. Retrieval from long-term memory alone is not enough for meaningful learning to occur. Students also need to change their own understandings of science into ones consistent with the scientific view (Alsop, Gould and Watts, 2002). Students do not change their ideas or conceptions easily but they change them only if they see that the more scientifically valid ideas make sense to them and are more fruitful than their own in explaining a phenomenon and making predictions. Therefore, in order for change to occur students must become dissatisfied with their existing knowledge and be aware of that there may be inconsistencies in their way of viewing the world. This requires a direct contrast between their existing ideas and intended scientific views. They need to test and develop their models and thought processes in familiar contexts, which they believe are real, representative of everyday experience and under their control. Once they can see that current ideas or conceptions are no longer relevant to solve problems then new learning occurs (Cimer, 2007).

Various strategies are suggested for teachers to use to challenge students' existing ideas. For example, peer interactions can be a valuable strategy by creating productive discussions. In such instances, students experience dissatisfaction with their existing concepts, develop plausible new concepts and see the relevance of new knowledge in different contexts. Furthermore, conducting investigations or inquiry can also strongly challenge students' existing ideas. They can apply their own ideas, observe the process, make predictions about the results and record the results of the experiment. When they achieve unexpected results or find that others disagree with their interpretations or see that their current ideas will not solve the new problem, their existing conceptions are challenged. As a result, they come to the understanding that they should either modify or discard these old ideas and construct new ones (Goodrum; Hackling and Rennie, 2001). Similarly, simulations in combination with practical work can be effective in helping students change their non-scientific conceptions (Peat and Fernandez, 2000). After determining students' existing ideas and conceptions and making students aware of them, teachers need to introduce scientific concepts to help them construct new knowledge (Glenn, 2001).

This explanation phase should be clear and short, and allow time for students to process new information and restructure their understanding. As learners' working memory, where they process information, is small, it takes at least five seconds to organise a 'chunk' of new information and to transfer it to long-term memory. Since the flow of the material during a class is typically much faster, the student's short-term memory is quickly overloaded and learning stops until a space is available in the short-term memory. As a result, students cannot always process the new information rapidly enough because they might lose attention and thus, start daydreaming or not paying attention in the lessons (Cimer, 2007). This is evidenced by research that indicates students retain 70 percent of the information during the first ten minutes of a lecture, but only 20 percent of the last 10 minutes, students' effective attention is 25-30 minutes. All these, therefore, suggest that teachers should give short breaks or provide examples for students to process new information in their working memory. When there is no new information coming, students can digest what is being said more readily. However, teachers should not rely on lectures too much for introducing new knowledge and skills because, as a traditional teaching method, lecturing can make students passive in the lessons, leaving too little time for them to process the new information. A strictly lecture-based presentation of facts and concepts may lead students to believe that everything has been figured out already and in order to pass their examination they must memorise facts and concepts instead of trying to understand them. In explaining new concepts or ideas, there are two important conditions that teachers should consider: creating attention in students and providing examples and opportunities for students to practise their ideas (Parkinson, 2004).

In order for students to comprehend new ideas or concepts and construct their own knowledge, they need to see clear examples of what the new ideas or skills represent. Furthermore, in learning new materials or skills, students should be given extensive opportunity to manipulate the environment (Joyce, Weil and Calhoun, 2000) as, according to Piaget (1978), students' cognitive structures will grow only when they initiate their own learning experiences. For example, Cimer (2007) suggested that teachers should provide tasks where students can engage in cognitive processing activities of organising, reviewing, rehearsing, summarising, comparing, and contrasting with other students, or with the teacher or working alone. In addition he wrote that teachers should encourage informal discussions and structure science activities so that students are required to explain and justify their understanding, argue from the data, justify their conclusions and critically assess the scientific explanations of a matter. He also suggested that teachers can demonstrate skills and work on a problem on the board whilst discussing it.

If the concepts taught at school are not related to students' everyday lives, they may fail to use them adequately outside the school. Thus, their knowledge may remain in the form of acquired isolated knowledge 'packages'. Effective learning requires students to apply newly acquired concepts or skills to different contexts (Cimer, 2007). He wrote further that as a result, they can achieve higher learning outcomes and use their knowledge or skills to solve the problems in their everyday life. For these reasons, teachers should create opportunities that allow students to apply their knowledge to real life situations. He suggested that teachers should:

> …….identify practical applications of concepts, use practical experiences and applications to make connections between concepts and 'real world' experiences in ways that enrich understanding of concepts, and show how knowledge of one set of concepts forms the foundation for learning about other concepts (p 313)

He suggested that teachers can employ various methods to help students to apply their knowledge, such as conducting practical work, field trips, simulations, writing activities and role-play.

Following is a brief discussion of some of these methods drawn from the literature.

A useful method for enabling students to participate in the learning process is to conduct practical work. The important point in doing practical work is to ensure that students are mentally active. It can provide a good opportunity for students to apply their newly acquired knowledge or skills and gain first-hand experience of phenomena talked about in theory (Millar, 2004; Amos and

Boohan, 2002). When students engage in practical work, they can test, rethink and reconstruct their ideas and thoughts. For these reasons, many studies reported that practical work improved students' learning and understanding (Millar, 2004; Dave, 2003). Dave (2003) argued that such positive outcomes may be as a result of students' gaining ownership over the concepts they learn as they 'discover' the knowledge themselves during practical work. Hands-on science education experiences can have lasting and personal effects on students (Hudson, 2007).

In relation to practical work, simulations can be used to replace laboratory work when it cannot be done in schools (Peat and Fernandez, 2000). So, they can help students understand invisible conceptual worlds of science through animation, which can lead to more abstract understanding of scientific concepts. Students can understand not only just what happens, but also how and why. Using simulations in science lessons also improve students' higher order skills like application, analysis and thus, help them comprehend the topic better (Hwang and Esquembre, 2003; Joyce *et al.*, 2000).

Field trips can provide students with meaningful contexts where they can connect their knowledge with the natural world and see examples and practical applications of scientific concepts or processes (Tytler, 2002; Griffiths and Moon, 2000). Fieldwork is not always possible due to a limited teaching budget and increasingly busy curricula. Yet, teachers can bring the natural world into the classroom by providing live plants, animals, pictures, models and the display of student work (Griffiths and Moon, 2000).

Recently, there has been much emphasis on participatory classroom activities because there is a general agreement that effective learning requires students to be active in the learning process (Parkinson, 2004). In addition, researchers believe that the more students are involved in the learning process, the more they learn the topic (Deboer, 2002). Taras (2002) suggested that student-centred learning has, in theory, promoted and brought about greater student participation and involvement. That for students to be at the centre of the learning and teaching process, their needs and requirements must be at the heart of this process, meaning can only be formed in students' minds by their own active efforts and cannot be created by someone else for the students. He explained further that this suggests that students are not simply passive recipients of information from the teacher, computer, textbook or any source of information during the learning process. That they have to wrestle with an idea in their own minds until it becomes meaningful to them. Joyce *et al* (2000) stated that the opportunity to exchange views and share personal experiences produces the 'cognitive conflict' that is fundamental to intellectual development. They suggested that in order to foster cognitive conflict, students need opportunities to pose questions about science, to work with others, to conduct investigations, present and defend their ideas, solutions, and findings, and assess their own and other students' reasoning. They wrote further that all these imply that they need to participate in the learning processes.

Deboer, 2002 and Stepanek, 2000 wrote that active learning techniques can empower students to make good decisions and take an active role in their own learning, increase their motivation to learn, foster and value the diverse choices of students and reduce disciplinary problems. They explained that researchers believe that this is as a result of a sense of ownership and personal involvement that active learning creates, that in active learning contexts students see their work as important because they feel important and their ideas and findings are valued. Amos (2002) argued that students' active participation also requires a positive, supportive learning environment in which they feel free to ask their own questions, express their ideas and thoughts and receive support and encouragement. He explained further that when students realise that their ideas and thoughts are valued and treated with respect by the group members, when they actively involve themselves in group activities, they feel more confident, and thus, participate more in the activities. Many different methods and strategies have been suggested for involving students in lessons and engaging them in active learning (Deboer, 2002; Goodrum et al., 2002; Trowbridge, Bybee and Powell 2000). However, in order for any method to be successful, effective lesson planning is essential. A lesson plan requires teacher to be clear about the sequence of the activities in the lessons, the purpose and goals of the lessons. The planning process involves clarification of the roles of the teacher and students. Thus, it makes it easier for students to follow the teacher's material and encourages them to participate more in the lesson and take responsibility for their own learning. For these reasons, effective lesson planning has a positive effect on students' learning (Glenn, 2001). He explained further that according to the above, teachers should allow some flexibility in lesson planning in order to encourage students to participate more in the lessons, that it is important to be sensitive to the mood of the class and if something is not going well to abandon it and move on or change task completely. Otherwise, a rigid lesson plan potentially hinders rather than helps the teaching-learning process, since it could prevent students from being involved in the lessons and reduce their creativity.

Questioning is the most common strategy that teachers use for involving students in the learning process (Amos, 2002; Glenn, 2001). Amos (2002) reported that up to one-fifth of what a teacher says in a classroom is likely to be in the form of questions. Amos, (2002) and Glenn, (2001) advised the teachers to ask open-ended, higher level questions from their students so as to encourage them to find out answers to the problems at hand and reveal their own ideas and thoughts. Also that if teachers ask open-ended questions, they allow students to think freely and flexibly, to express their own ideas and thoughts without thinking that they have to give one 'right' answer and they promote successful discussions that stimulate student participation. Amos (2002) argued that closed and subject-oriented questions that rely on linear processes and logical reasoning discourage students from thinking differently from the teacher and may deter students from answering the questions asked. In addition to the nature of the questions asked, the process of asking questions is also important for students' learning and development. Providing sufficient 'wait time', about 3-5 seconds, after asking a question for students not only increases student participation but also provides them with opportunity to think critically and create more ideas and responses (Amos, 2002; Trowbridge *et al.*, 2000).

Role-playing can also be a useful teaching and learning activity to encourage students to participate more in the lessons and facilitate their understanding. However, researchers report that role-playing in science lessons is underrated and underused, often because of misconceptions about what role-play is and how it can be put to use in science education (McSharry and Jones, 2000). They pointed out that the theory behind the use of role-play in science teaching and learning supports 'active', 'experiential' or 'student-centred' learning. Therefore, students are encouraged to be physically and intellectually involved in their lessons to allow them to both express themselves in a scientific context and develop an understanding of difficult concepts and help them to learn complex topics.

Inquiry-based teaching and learning (Deboer, 2002; Trowbridge *et al.*, 2000) and cooperative learning groups (Goodrum *et al.*, 2001) are also useful contexts where students actively participate in learning process to develop their own understandings of scientific knowledge. In short, student participation is necessary for their learning. Active participation can increase students' learning, understanding and motivation to learn. Teachers should make sure that students are mentally active in the lessons and create opportunities for them to participate in the lessons. In recent years, there has been a growing movement to integrate inquiry into science education (Deboer, 2002; King, Shumow, and Lietz, 2001; Trowbridge *et al.*, 2000). The importance of inquiry grew from Dewey's ideas. Cimer (2007) citing Dewey suggested that citizens in a democratic society should be inquirers with regard to the nature of their physical and social environments and be active participants in the construction of society. That they should ask questions and have the resources to find answers to these questions, independent of external authority. Since there is a shared, collaborative aspect to life in a democratic society, students also need to develop a capacity for communal inquiry into the nature of the world. That therefore, formal education needs to give students the skills and dispositions to formulate questions that are personally significant and meaningful to them. Trowbridge *et al.*, (2000) defined inquiry as the process of defining and investigating problems, formulating hypotheses, designing experiments, gathering data and drawing conclusions about problems. A potential result in inquiry-based teaching enables students to gain insights into the nature of scientific inquiry and understand how and why to apply the scientific method at the same time as they come to understand the subject. They can also understand what science is like and what scientists do (Amos and Boohan, 2002).

Engaging in inquiry can also help students develop a wide range of skills, such as psychomotor and academic or intellectual skills Psychomotor skills involve doing something physical, like gathering and setting up apparatus, making observations and measurements, recording data and drawing graphs while academic or intellectual skills include analysing data, making comparisons, evaluating results, preparing reports and communicating results to the others or the teachers. Furthermore, students’ attitudes and dispositions such as curiosity, inquisitiveness, and independence of mind, freedom from external authority, and a personal search for meaning about the world can also improve. Therefore, it would appear that inquiry-based learning can prepare students to be lifetime learners rather than classroom-only learners (DeBoer, 2002; King *et al.*, 2001; Trowbridge *et al.*, 2000).

It is not enough to supply only a sterile classroom or lecture hall for students. Instead students need a range of resources including books, a laboratory with enough equipment, library, and computers (Joyce *et al.*, 2000; Trowbridge *et al.*, 2000). Teachers should provide focus, which means that inquiry is a purposeful activity, a search for particular meaning in some event, object or condition that raises questions in the inquirer’s mind. It is stimulated by confrontation with a problem. Knowledge is generated from inquiry. They should provide 'low pressure'. This indicates that students will gain their reinforcements directly from the success of their own ideas in adding meaning to the environment. In order to provide 'low pressure' to students, teachers should be positive and flexible to encourage students further (Joyce *et al.*, 2000). There is also need for a positive and supportive learning environment in order to foster student inquiry and to encourage students to ask their own questions. In non-threatening and trusting classroom environments, students can show their willingness to seek understanding and express their curiosity. On the contrary, in such classrooms where the conditions are not supportive and encouraging, students may not put forward questions (Alsop *et al.*, 2002; Amos, 2002; McKeon, 2002). Joyce *et al* (2000) stressed the teachers’ role in encouraging student inquiry is often dependent on the creation of a co-operative social environment, where students learn how best to negotiate and solve conflicts necessary for problem-solving. They suggested that teachers should also

> *guide students in methods of data collection and analysis, help them frame testable hypotheses, and decide what would constitute a reasonable test of a hypothesis'* (p98).

Effective teaching requires teachers to check continuously the development of students' understanding and give detailed positive feedback in order to make sure that students correctly integrate new knowledge into the existing knowledge structure (Cimer 2007). In addition, in order to identify and correct students' mistakes at an early stage before they become too deeply embedded, teachers need to continuously monitor and evaluate students' understanding (Hipkins *et al.,* 2002). The process of evaluating students' work or performance and using the information obtained from these practices to modify teachers' and students' work in order to make teaching and learning more effective is known as formative assessment. Research has shown that it has great potential for improving the quality of teaching and learning and that it is the essential feature in good teaching as well as in efficient learning. Furthermore, if assessment occurs early in the teaching-learning sequence, it can reveal information about students, which can be used to guide the planning of teaching so that it takes account of students' existing conceptions (Cimer, 2007).

The emphasis of formative assessment on providing students with continuous feedback on their performance aims to engage students in self assessment of their learning, and hence, it can be argued that formative assessment can increase student participation in the learning process (Cimer, 2007). Students engaging in self assessment have more control over their learning and use the feedback to modify their learning behaviours (Goodrum *et al.*, 2002). Feedback helps students find out how well they understand the new material, what they have done correctly and what their errors are (Joyce *et al.*, 2000). Therefore, educators reported that effective teachers frequently provide feedback specific to the subject matter being covered and if necessary, take remedial action, such as providing further explanation or repeating the key ideas and concepts. Taking such remedial action can improve students' learning. The important point in giving feedback to students is to help them discover their own mistakes, rather than simply telling them what they have done wrong or the pieces they are missing (Tytler, 2002; Stepanek, 2000).

Many researchers such as Akiri and Ugborugbo (2009), Oredein and Oloyede (2007), Ezeasor (2003) and Olatoye (2002) worked on the influence of teacher effectiveness on students' learning outcome as measured by students' academic performance. For example Akiri and Ugborugbo (2009) researched on the influence of teachers' classroom effectiveness on students' academic performance, reported that effective teachers produce better performing students. Also Ezeasor (2003) in her study on school environment and teacher effectiveness, found that teacher effectiveness has a positive and significant effect on students' achievement in biology. Osokoya (2002) also discovered that effective science teaching depends largely on the teacher and availability of equipment. In her own contribution Erinosho (2003) wrote that the problem is that science as it is taught in schools is abstract and not relevant to students' experience, also the approach to science learning in typical science classes is mainly by parroting and regurgitation of facts with virtually no link with the immediate environment of the learners. That this is most inappropriate as it does not promote deep understanding and application of scientific principles and theories.

Olatoye (2002), in his own findings concluded that the problem of low performance of students in the science subjects is therefore a major reason why teaching and learning of science should be improved in our schools. That we cannot hope for science and technological development in a situation where performance of students in the science subject is on the downward trend. He suggested that science subjects must be taught in line with the objectives of science teaching, that one of the urgent needs in Nigeria is how to improve the teaching and learning of science. That the condition of science teaching and learning in schools is very discouraging, and it calls for all stakeholders of education to rise up to these challenges in the interest of national development. That the teaching and learning of science needs serious improvement because of the low performance of the students in science subjects, chemistry inclusive.

It has been reported that the manner in which science subjects are taught in Nigeria secondary schools shows that majority of science teachers use the traditional lecture method approach (Abudu and Gbadamosi 2014, Agbowuro, 2008; Usman, 2000). Findings from studies show that most science teachers do not encourage students' active participation in the teaching and learning process. There is also inadequate provision for practical activities and those provided are often inappropriate to produce the desired learning effects. Experiments in science subjects are often turned into demonstrations by the teacher for students to observe and to copy notes draw diagrams during chemistry lessons. Effective science teaching and learning ought to involve students' active participation in the teaching and learning process. Lack of such active participation of students has been identified as one of the factors responsible for poor academic achievement in science subjects (Cleaves and Toplis, 2007).

According to Greenwald (2000), the best way for a student to learn science is to experience challenging problems and the thought and actions associated with solving them. In his own contribution Ekpete (2002), wrote that in order to solve chemistry problems in an acceptable manner, the problem solver must have both the conceptual, scientific and procedural knowledge. Mathematics problems are often encountered in areas of science and technology industries, economics, education, military warfare, medicine and even in government and these variety of problems require acceptable mathematical solutions. Problem-solving in mathematics is based on some closely interwoven criteria. For example, one mathematical concept of matrices in Algebra can be used to solve a multitude of problems arising from diverse academic fields such as Physics, Chemistry, Economics, Sociology, Psychology, Geology, Astronomy and Statistics (Sule, 2000). The particulate unobservable nature of particles and mathematical nature of much of chemistry content make chemistry difficult to learn and understand (Taber, 2002).

Reviewed studies show that the achievement tests scores of students are used as a measure of not only the students' achievement but also the teachers' achievement, performance and effectiveness (Hudson, 2007). Researchers such as Joshua, Joshua, and Karitsoms (2006) and Berk (2005) were of the opinion that test based students' achievement gains have predictive power but provide little insight into both the teachers and the students' strengths and weaknesses, except factors such as students' attitude, classroom environment such as class size, teachers' qualification. This is the reason why this study looked into these factors and the researcher made sure the teachers in the researched schools are professionally qualified. Also the schools have the necessary apparatus for the study.

2.4 Problem-Solving as an Inquiry-Based Instructional Strategy

The first attempt to cite problem-solving as a useful teaching strategy was made by John Dewey cited by Raimi (2002) in his book "How we think". In his view, reflective thinking is the aim of education. It would innate activity with a deliberate and conscious goal, which can result in planned procedure and possible invention. The five phases of his reflective thinking heuristics expressed in instructional terms reveal the rudiments of the present conception of problem-solving stages. From a review of literature on various problem-solving models, the five step model of John Dewey passes as a benchmark because all present models are predicted on this plan with either one or two steps plus or minus the five steps model he enunciated.

Although this study was concerned with problem-solving, the researcher realised the non-unitary nature of the term and was compelled to give a more introspective meaning of the word 'problem'. According to Oxford Advanced Learner's dictionary problem is "a thing that is difficult to deal with or to understand, or a question that can be answered by using logical thought or mathematics" Pg 1157. 'Problem' is seen as occurring in a situation where there is some obstacle between the given problem and the goal. If an academic problem is perceived as this barrier or intervening variable, then it requires planning, thinking and channeling of thought process towards finding solution to the problem. The ability to overcome the barrier will also depend on whether or not the problem-solver possesses sufficient information in his memory. To the researcher what is considered problematic is relative, in a laboratory situation for instance, a 'problem' arises when the student faces an experimental task to which answers or solutions are not readily available. A number of problems exist in nature for which solutions are being sought in everyday life situations (Sule, 2000).

In his own contribution Rusbult (2008), defined a problem as any situation where one has an opportunity to make a difference, to make things better. Reid and Yang (2002) provided a way to categorise problems by considering the data given, the method to be used, and the goal to be reached. That there are some parallels called the ‘operators’ and ‘operator restrictions’. If these are all known, then the problem is simply a routine application of a known procedure to handle data to reach an established goal– an algorithmic exercise. On the other hand, if none of the three (data, method and goal) are known then the problem is truly an open one. With these three variables, they specify eight types of problems (Table 2.1).

Table 2.1 The eight problem types

Type	Data	Methods	Goals/outcome
1	Given	Familiar	Given
2	Given	Unfamiliar	Given
3	Incomplete	Familiar	Given
4	Incomplete	Unfamiliar	Given
5	Given	Familiar	Open
6	Given	Unfamiliar	Open
7	Incomplete	Familiar	Open
8	Incomplete	Unfamiliar	Open

In all spheres of human endeavours especially in the educational sector, solution to problems or surmounting an obstacle is the ultimate goal of man. This brings us to the concept of ‘problem solving which is the hub of this work. The Oxford Advanced Learner’s Dictionary defines it as “the act of finding ways of dealing with problems”. It has become fashionable to view ability to solve problems (theoretical or practical) as an index of learning. Problem solving is also seen as the highest form of human mental activity, it is converting an actual current state (the NOW-state) into a desired future state (the GOAL-state) (Rusbult, 2008). Orimogunje (2008) described it as the ability to reason logically, think critically and at the end solve problems that come the learners’ way in the environment. It requires overcoming all the impediments in reaching a goal (Bilgin, 2005). In his own contribution Kirkley (2003) wrote that in the early 1900s problem-solving was regarded as a mechanical, systematic and frequently abstract (de-contextualized) set of skills such as those employed to solve riddles or mathematical equations.

Problem-solving involves knowing what to do in the situation of not knowing what to do. It is not only finding the correct answer, but also applying appropriate actions which cover a wide range of mental abilities. Students should realize why and what they are doing, and know the strengths of these strategies, in order to understand them completely and be able to select appropriate ones (Erol, Selcum and Caliskan, 2006). In the words of Erdemir, (2009), “Problem-solving also involves a student’s willingness to accept challenges. Accepting a challenge in this context means that the student is willing to find appropriate methods to solve a problem”. Problem-solving means the application of already acquired knowledge of ordered science process skills (by the solver) to arrive at solution to novel and related chemical problem (Raimi, 2002). In the context of this definition the level of the process skills possessed by the solver (student) is very important, because this is what he or she will apply when solving the problem. Hence the assessment of the level of the chemistry process skills possessed by the student after exposing him or her to the treatments were determined in this study. Problem-solving is a mental process and is part of the larger problem process that includes problem finding and problem shaping. It is considered the most complex of all intellectual functions, problem-solving has been defined as higher order cognitive process that requires the modulation and control of more routine or fundamental skills. There are several methods of studying problem-solving which are: Introspection, Behaviourism, Simulation, Experiment and Modeling (Wetzel, 2008). This study is on Experiment and Modeling.

To the researcher problem-solving is the application of the skills possessed by the problem solver (student) during the guided procedural step by step teaching and learning to solve problems in the environment and for technological development of the nation. Some common elements of problem-solving are obvious from these definitions and explanations:

- Existence of a problem.
- Imminence of a solution.
- Potential problem solver.
- Possession of relevant information and process skills needed to solve the problem.
- Proper application of previous knowledge (content and procedural) process skills to the solution of the problem.

Problem-solving is a higher order cognitive skill which demands many abilities, sometimes requiring much effort from the solver. It is a process in which various reasoning patterns are combined, refined, extended and invented. It is much more than substituting numbers in well known and practised formula. It deals with creativity, lateral thinking and formal knowledge. Research has tried to correlate some cognitive variables, such as formal operational reasoning, working memory capacity, specific knowledge, concept relatedness and idea association, to science achievement and problem-solving ability (Lee, Tang, Goh and Chia, 2001). Problem-solving is the process of investigation where the solution is not obvious to the investigator at the initial stage. The relevant concepts in the cognitive structure of the student must be adequate before the students will be able to solve a given task or problem effectively. A number of theories of learning processes have revealed that the only way an individual can learn how to solve confronting practical life problems is through the ability to solve many of such daily practical problems (Sule, 2000). Students who can successfully solve a problem possess good reading skills, have the ability to compare and contrast various cases, can identify important aspects of a problem, can estimate and create analogies and attempt trying various strategies, problem-solving is a situational and context bound process that depends on the deep structures of knowledge and experience. The process of teaching problem-solving is a suitable approach which involves students in higher order thinking operations like analysis, synthesis and evaluation (Normah and Salleh, 2006).

In active learning process, learning is no longer a standard process, but it transforms into a personalized process. Here, the skills of problem-solving, critical thinking and learning to learn are developed. Humans face various problems in their lives and they try to find particular ways to solve these problems. In this respect, it is important for students to be prepared for the future by facing real or real-like problems in their learning environment and producing appropriate solutions to these problems. What is expected from education is to enable individuals to become an effective problem solver in their actual lives (Chin and Chia, 2004; Walker and Lofton, 2003). In problem-based learning model, main tools which are used can be stated as the case study method, problem-solving based learning approach, project-based learning approach and cooperative learning approach. The problem-based learning model which is closely connected to these learning models and methods seems to be enriched by increasingly spreading new methods such as ‘portfolio based learning’ and ‘experimental learning’ (Akınoğlu. and Tandoğan, 2007). This study is on problem-solving based learning approach.

2.5 Problem-Solving Models

Several researchers in problem-solving process have developed different theoretical models content-based domain. The previous knowledge of the problem solver was not taken into consideration. Based on this flaw, researchers in content based domain argue that success in solving a problem depends on the learners’ conceptual and procedural knowledge based on step by step approach. The following researchers developed models with different steps Wallas, Dewey, Polya, de Bono, Gordon, Newell and Simon and Meadows cited in Ishola, (2000). They based their problem-solving process on prescriptive models studies, focused on regulative acts of the problem solver in a content free domain. Consequently researchers shifted their base to systematic approach which will enhance success and confidence in tackling problems. Many problem-solving models have been used in science instruction and much research has centered on problem-solving in terms of what models/ strategies teachers and learners use in solving different types of problems and difficulties encountered in problem-solving (Ashmore, Frazer and Casey, Mettes, Pilot, Rossink, Karamer-pals, Slack and Steward, Smith, West cited in Ishola, (2000), Onwioduokit, (1989); Ikitde, (1994); Ige, 2003). Common to all the models are four distinct stages in problem-solving:

- Problem definition.
- Selection of information for solution.
- Reasoning from problem to solution stage.
- Evaluation.

In her investigation of aspects of students' problem-solving difficulties in ordinary level physics, Ishola (2000) identified the following as major components of any numerical physics problems where students usually have difficulties. These are: probable difficulties associated with understanding given questions and their values, knowledge of physical units in which derived answers are expressed, possession of relevant numerical skills. She is of the opinion that problem-solving starts with a person's identification and understanding of the issue in question. This skill, according to her depends on knowledge of the content as well as the way the problem is linguistically posed. Ishola (2000) citing Egbugara devised what he called Ibadan Seven Step Physics Problem-Solving Model (ISSPPSM) to be used by physics teachers and students of secondary schools in Nigeria to solve numerical problems in physics. Ishola (2000) adopted this model and compared the effectiveness with the amalgamation of Selvaratnam-Frazer model with additional intensive practice, feedback and remediation strategies, which enhanced students' intellectual knowledge and problem-solving behaviour. Few models were developed for practical and experimental problem-solving, these are: Laboratory Problem-Solving Model (LAPSOM) by Onwioduokit (1989), Researchers Experimental Problem-Solving Model (REPSOM) by Ikitde (1994) and Inquiry- based framework for practical problem-solving by Ige (2003).

Inquiry-based framework for practical problem-solving adapted by Ige (2003) from West (1992). It is also a seven-step model as follows:

1 Identifying problem.
2 Identifying issues related to the problem.
3 Framing objectives.
4 Determining strategy.

5 Embarking on activities.

6 Presenting and discussing of result.

7 Evaluating of performance.

This study made use of two problem-solving models which are: Laboratory Problem-Solving Model (LAPSOM) by Onwioduokit (1989) and Hands-on and Minds-on Problem-Solving Model (HAMPSOM) developed by the researcher.

Laboratory Problem-Solving Model (LAPSOM).

This was developed by Onwioduokit (1989). The developer found that the existing problem-solving models in science were principally designed for and applied only in theoretical contexts. His review of literature does not reveal any previous attempt to apply existing problem- solving models in practical (laboratory) contexts. He undertook the construction of a Laboratory Problem-Solving Model (LAPSOM) to facilitate students' development of skills in practical physics. It is in two parts. The first part shows a general strategy for solving practical problems, it specifies the systematic processes for laboratory problem-solving. The second part concerns how students are taught to use this systematic approach (Instructional Guide) (p 74-75). The first part of LAPSOM consists of five procedural stages which altogether comprises eight action steps (Figure 2.2). The reversible nature of the procedure ensures cognitive and process flexibilities which are required at each stage for arriving at the problem objective.

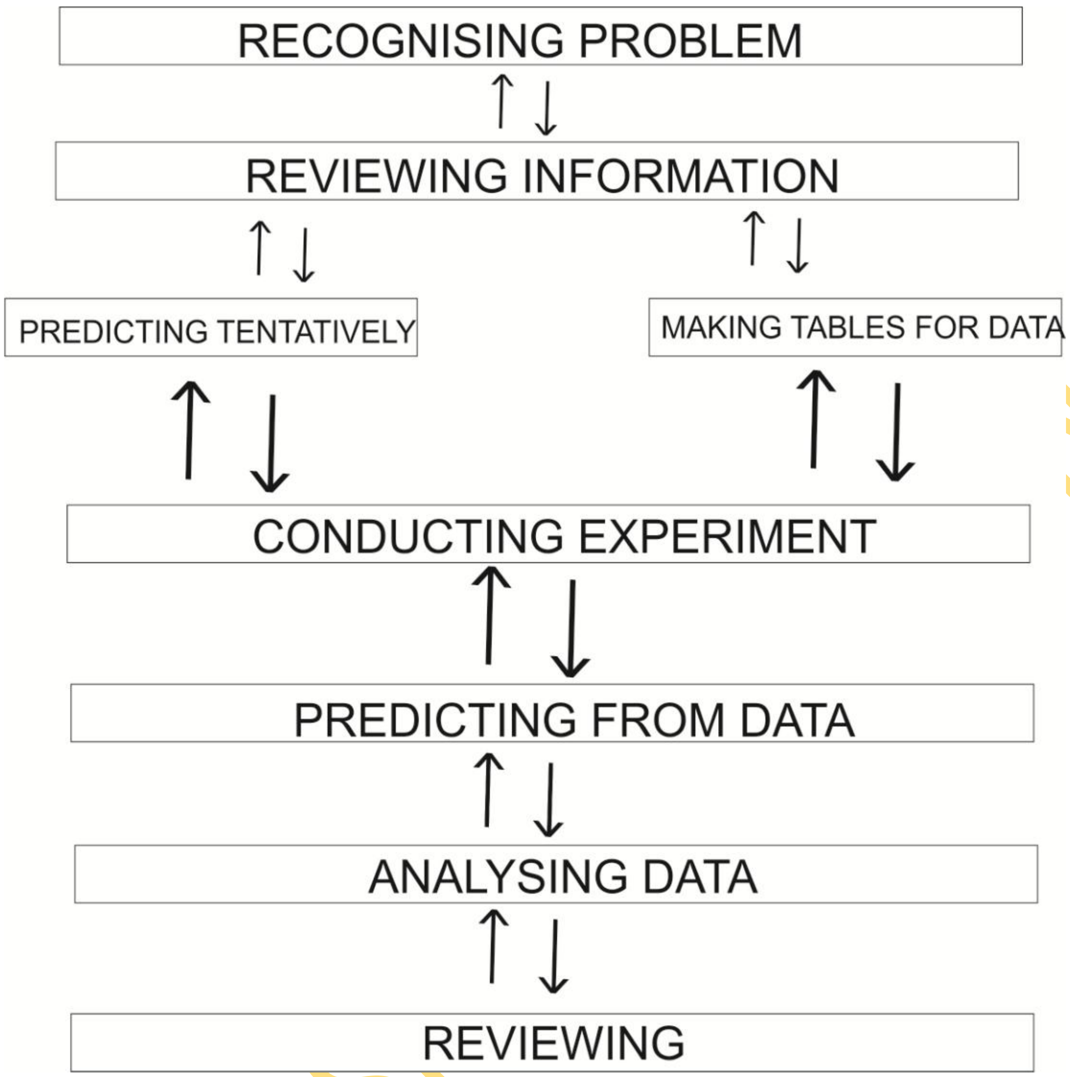

Figure 2.2 **Laboratory Problem Solving Model (LAPSOM)**

LAPSOM Part One: General Strategy

Stage 1: Recognize the problem and apparatus

Any meaningful attempt to solve a problem should start from a correct identification of the problem. The first step in LAPSOM requires that the students should be able to recognize the main problem given and to break it down to sub problems. He should be clear as to what experiment is required and what problem the experiment seeks to solve. He should be able to identify the apparatus provided and clearly understand their functions.

Stage 2: (a) Recall Background information

Practical problems are always content-referenced. Therefore the information which a student needs for arriving at a solution as well as the reasoning processes which lead to the solution of the problem are important factors. The first step in this stage therefore demands that the problem-solver does a “backward reasoning” to bring to mind the theoretical background of the problem. It is with such background that he would be able to have a clear picture of the experiment and be able to handle the variables, mathematical relationships between variables, as well as be able to sketch a diagram of how he intends to set up the apparatus.

Stage 2(b): Make prediction

This sub-stage involves making tentative hypothesis (predictions) about the solution of the problems. This is forward reasoning. With this, the relationship between the dependent and independent variables, the nature of expected graph and perhaps the solution to the problem could all be predicted.

Stage 2(c): Drawing up a table for data

The combination of forward and backward reasoning will enable the problem solver to draw up an appropriate table for data expected during experimentation in stage three.

Stage 3(a): Experiment

With the information obtained in stages one and two, the problem-solver is expected to design an experiment, set up and manipulate the apparatus in order to solve the problem. This sub stage is referred to as the main laboratory session.

Stage 3(b): Make more reliable predictions from data

On obtaining data as an outcome of manipulating the apparatus, the problem solver at this stage matches the tentative prediction made in 2(b) with the data in order to formulate more reliable hypotheses (predictions). This sub stage marks the beginning of the post laboratory session that ends in stage five.

Stage 4: Analyze the data

The data obtained from the experiment is subjected to some statistical treatments including graph plotting. The type of analysis made is often determined by the nature of the problem identified and the preliminary analyses made. Appropriate calculations are then carried out to arrive at solutions to the problem(s).

Stage 5: Evaluate solution and experiment

The problem-solver needs to substitute the formulated or given data to see whether or not there exists a balance between both sides of the equation. Also he matches the solution obtained with the modified predictions; he explains results and makes suggestions for an improved experimentation to solve similar problems.

Theoretical background of Laboratory Problem-Solving Model (LAPSOM)

The laboratory problem-solving model (LAPSOM) has its root in the process approach of science and in the philosophy of instrumentalism derived from John Dewey's Pragmatic view cited in Onwioduokit (1989).

Dewey's five steps of pragmatic problem-solving are as follows:

(1) Sensing the problem.
(2) Locating it and delimiting it precisely.
(3) Collecting possible data that is, thinking of possible solution.
(4) Sifting data, that is, weighing the merits and demerits of the possible solutions and
(5) Selecting one solution for verifying and accepting or rejecting it according to the outcome of the experiment.

Throughout Dewey's career, he stressed the importance of having pupils learn scientific method or problem-solving through reflective thinking. LAPSOM was adapted from other existing problem-solving models Mette, Ashmore, Frazer and Casey and Frazer. Three things are centrally crucial in any problem-solving model, be it for theoretical, numerical or practical problem-solving. These are:

(1) Identification of problem.
(2) A search for solution and
(3) Evaluation of solution.

It is mostly upon these three phases that other phases or activities are built.

Hands-on and Minds-on Problem-Solving Model (HAMPSOM)

The researcher developed this model that will meet the needs, demands and complexities of practical, experimental and theoretical problem-solving in science.

The procedural guide (instrumental) is in two parts. The first part shows a general strategy for solving problems in science by specifying the systematic processes to such experimental problem-solving (Figure 2.3). The second part is concerned with how students are guided by the teacher to use this systematic approach and can also be regarded as the operational phase (Instructional Guide) (pg 76-78).

HAMPSOM Part One: Structure and General Strategy

The first part of this problem-solving model consists of five procedural stages which are further broken down into fourteen action steps as shown in figure 2.3. These stages are sequential, hierarchical (one concept leads to another) and the degree of success achieved at a stage leads to that of subsequent stages. This in turn ensures cognitive and process flexibilities needed during the teaching-learning process until solution is obtained. For instance errors made in the manipulative phase of an experiment are likely to lead to erroneous observations, which in turn will cause wrong or incomplete conclusions to be drawn considered from the conventional perspective of teaching science. Stage 1 is referred to as pre laboratory session, stages 2 and 3 as the laboratory session and stages 4 and 5 as post laboratory session. The details of the stages are as below:

Stage 1A: Problem Perception

A correct identification of a problem should be the start of any worthwhile attempt at finding solution to any problem. A student (problem solver) should therefore read with understanding any practical question posed and be able to state the problem in a clear and unambiguous terms. Without a clear concept of the problem or what the experiment specifically demands which is the aim of the experiment, he cannot identify the apparatus.

Stage 1B: Acquiring Related Theory

The theoretical aspect or the content is the foundation of practical problems. The information which the students need for arriving at the solution and the reasoning processes which lead to the solution of the problem are important factors. This background would enable them to have a clear picture of the experiment and be able to tackle the remaining stages.

Stage 1C: Planning Experiment

The knowledge of the content enables the students to draw the diagram for the experiment, identify the apparatus and arrange them according to the diagram.

Stage 2A: Recalling Theory and Making Tables.

Any student that is lacking in the theory of a particular experiment is bound to have problems with the interpretations, discussions and conclusion of experiment. Being fully equipped with the theoretical background, the student would have a clear picture of the experiment and experimental process and can predict tentatively what the result is likely to be if the experiment proceeds favourably. Appropriate tables can now be drawn, knowing the nature of results expected.

Stage 2B: Experiment:

This is the stage that lends itself to discover the answer or solution which cannot be determined by merely looking it up in a science textbook. This act of mental manipulative exercises can lead to acquisition of skills and evaluating an original design. The experiment should be repeated and more than one readings taken.

Stage 3A: Observation

The student is always expected to make accurate report of any observations made without recourse to theory. To forestall falsification of results, the teacher should always insist on seeing the result of any observation made before being recorded by the problem solver (student). By so doing the students will learn the art of trained and accurate use of senses to collect information.

Stage 3B: Collecting and Recording Data

Data collection and recording are very important any error at this stage will affect the result and may lead to performing the experiment again. These involve the different methods of data collection, drawing tables for recording of such data.

Stage 4A: Analysing of Result

Data collecting and data analyzing form a continuous process in that, the data collected determines the direction of the analysis. The use of appropriate method of analysis is important.

Stage 4B: Interpreting, Predicting data and drawing conclusion.

This section requires the student to explain the results collected by several observations as well as attempt a synthesis of the data accumulated during the investigation. Such explanation is based on existing knowledge in the area. If the student fails to obtain correct results, he has experienced the experimental process and possess the necessary skills. He is in the best position to highlight sources of error and to suggest improvement to the design of the experiment. For the students will find it easier to reject his incorrect hypothesis which he proposed as a result of his experimentation.

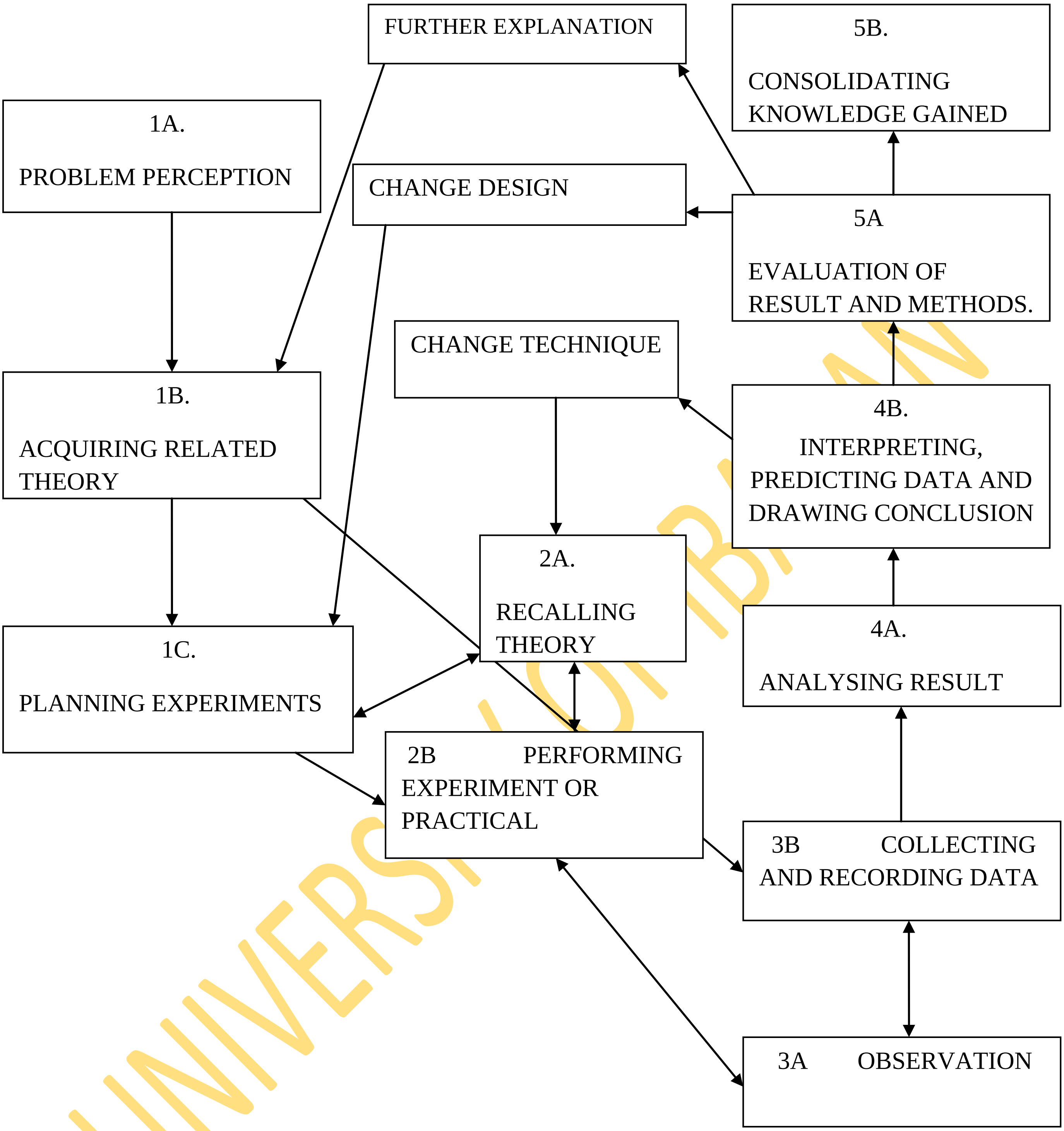

Figure 2.3: Hands–On and Minds-On Problem-Solving Model (HAMPSOM)

Stage 5A: Evaluation of Result and Methods

The student having completed his investigation is asked to look back at his results and methods and suggest new ideas and ways to conduct the investigation.

Stage 5B: Consolidating Knowledge Gains and Change in Technique.

If the result is considered sound following a proper procedural appraisal, a solution is said to be at hand. Sometimes more in depth examination of the sources of error could lead to suggestions on the improvement of the design to yield better results or by giving further explanation by the teacher. A change of technique may be necessary if the result is not the expected one.

For this study the effects of Laboratory Problem-Solving Model (LAPSOM) and Hands-on and Minds-on Problem-Solving Model (HAMPSOM) and control using their instructional guides on students' attitude to and achievement in practical chemistry were determined, and compared to know which effect is greater.

Theoretical background of Hands-on and Minds-on Problem-Solving Model (HAMPSOM)

The five phases of John Dewey cited by Raimi (2002) reflective thinking heuristics expressed in instructional terms reveal the rudiments of the present conception of problem-solving stages. From a review of literature on various problem-solving models, the five step model of John Dewey passes as a benchmark because all present models are predicted on this plan with either one or two steps plus or minus the five steps model he enunciated. HAMPSOM was developed using the knowledge of two problem-solving models by Selvaratnam and Frazer (1982) and Ikitde (1994), because of the unique nature in using the philosophy and instrumentalism of John Dawey's pragmatic view with the four distinct stages in problem-solving models: These are:

- Problem definition.
- Selection of information for solution.
- Reasoning from problem to solution stage.
- Evaluation.

In addition HAMPSOM incorporated intensive theoretical background and teacher guided discovery learning.

Selvaratnam and Frazer (1982) develop more attractive model for chemistry.

The model specifies five steps:

(i) Clarifying and defining the problem
(ii) Selecting the key equation
(iii) Deriving the equation for the calculation
(iv) Collecting the data, checking the units and calculating
(v) Reviewing checking and learning from the solution.

Researchers Experimental Problem-Solving Model (REPSOM)

This is a five step model developed by Ikitde (1994) for biology. It is a straight chain model connected to sub groups irreversibly. These are:

1A Problem perception
1B Selecting apparatus
2A Recalling theory
2B Making tables
3A Experimentation
3B Observation
3C Recording data
4A Analysis of Results
5A Evaluation of solution
5B Consolidation knowledge gains
5C Change in technique.

2.6 Students’ Attitude to Science and Practical Chemistry

According to Oxford Advanced Learner’s Dictionary, attitude is the way that we think and feel about something or the way that we behave towards something that shows how we think or feel. Attitude according to the *Encyclopedia of Education* is a predisposition to respond in a certain way to a person, an object, an event, a situation or an idea. An attitude towards something consists of a person’s collection of facts about the subject, which may enable her to feel antipathy towards it, and manifest in either acceptance or avoidance of the subject. Oguntade (2000) defines attitude as the effective disposition of a person or group of persons to display an action towards an object based on the belief that such a person or groups of persons has about the object. Attitude towards science denotes interest or feeling towards studying science. While attitude in science means scientific approach assumed by an individual for solving problems, assessing ideas and making decision. Scientific attitudes embrace all scientific processes of gathering information with no subjectivity, skepticism or prejudice for the advancement of science. These processes can be objectively and confidently carried out by skillful individuals (Bassey, 2002). Among the factors that relate to the students’ attitude towards science, the researchers have identified the following: gender, age, education level (elementary school, secondary school, high-school, etc.), type of school (government or private school), the students’ school results in sciences and their classmates’ influence, self-image, social self perception, their family’s socio-economic status (parents’ education, jobs and monthly income), teaching methods, the parents’ attitude towards sciences, the students' cognitive style, their interest in a certain type of career, social view on science and scientists (Adesoji, 2008).

Learning to solve problems is a primary objective in learning science, as problems are an inevitable fact of life. By solving problems, a student needs to think and make decisions using appropriate strategies. Students' success in achieving their goals will encourage them to develop positive attitude towards problem-solving (Erdemir, 2009). Anderson and Dill (2000) indicated that attitudes are seen to be dynamic in nature and under constant change as they interact with behaviour and must be viewed in probabilistic rather than deterministic terms because of the complexity of structure of an attitudinal network. They stressed that attitude cannot be observed directly, rather they have in the past been inferred from what a person says or does, that attitude measurement has become a common part of research into schools and schooling throughout the world. That attitude is assumed to have an affective component of how students are seen by peers and themselves. They offered some generalizations about attitude:

- Students tend to have positive attitude towards school and the subject matter taught at school at all grade level.
- The attitude of students towards school and school subjects tend to become less favourable over their years at school.
- Students tend to like certain subjects e.g. science, sports, reading more than others (e.g. mathematics, writing and agricultural science).

Also that the relationship between attitude and achievement is generally moderate and positive provided the sample is not contaminated by selection bias. Lastly, that attitude tends to be influenced by appropriate change in school programme. They recommended that the measurement of attitude should become more common in schools particularly since they influence future participation in schooling and subject choice. Aiken (2000) wrote that attitude affects people in everything they do and in fact reflects what they are, hence a determining factor of students' behaviour.

According to Gonen and Basaran (2008), Ogunkola (2002) and Yoloye (1994) the attitude of a learner towards science would determine the measure of the learners' attractiveness or repulsiveness to science. This will invariably influence the learners' choice and even achievement in that subject. Normah and Salleh (2006) indicated that students' attitude and interests could play a substantial role among pupils studying science. Several studies, such as Gonen and Basaran (2008), Ajzen and Fishbein (2000) and Wilson, Ackerman and Malave (2000) reported that students' positive attitude towards science probably correlate highly with their achievement in science. Research has demonstrated that attitude toward science change with exposure to science but that the direction of change may be related to the quality of that exposure, the learning environment and teaching method (Cracker, 2006). There is the need to advance a variety of teaching methods, having to do with heuristic problem-solving in order to promote positive attitude of student towards problem-solving (Sule, 2000). Adesoji (2008) maintained that problem-solving strategy is probably a basic means of changing students' attitude towards science. The effect of solving problem on a student's attitude toward science is incredibly important because problem-solving requires patience, persistence, perseverance and willingness to accept risks (Udousoro, 2002).

"In developed countries, it has been determined that goals of science are never fully realized, that students do not like science lectures and that most have no preference for science". Though scientific concepts are functioning in daily life but these are difficult and complex in nature. In learning these concepts, students' attitude and interests could play a substantial role among pupils studying science (Normah and Salleh, 2006). Students can succeed in science subject if they have positive attitude towards science. In science education, "The affective outcomes of instruction are as important as the cognitive outcomes. The affective domain is characterized by a variety of constructs, such as attitudes, preferences, and interests. But negative attitude toward a given subject leads to lack of interest and avoidance of the subject". It means, a positive attitude toward science will lead to a positive commitment to science that will effect students' lifelong interest and learning in science (Erdemir, 2009). According to Salta and Tzougraki, (2004), "Attitude is a tendency to think, feel, and act positively or negatively toward objects in our environment". Attitude organises thoughts, emotions and behaviours towards a psychological object. Some attitudes are based on people's own experiences, knowledge and skills, and some are gained from other sources (Erdemir, 2009). It can be concluded in words of Craker (2006) that attitudes are learned, not inherited, that the attitudes toward science change with exposure to science, but that the direction of change may be related to the quality of that exposure, the learning environment, and teaching method. It can be said that a negative attitude towards a certain subject makes learning or future-learning difficult. "A positive attitude toward science leads to a positive commitment to science that influences students' lifelong interest and learning in science" (Craker, 2006).

Erdemir, (2009) indicated that "Many researchers argued that teaching methods have a great impact on students' attitude to learn a subject". That's why the researcher opted to find out the effects of problem-solving approaches on students' attitude to practical chemistry. Many researchers believe that if students are allowed to demonstrate higher cognitive abilities through problem-solving, either through a teacher centered approach or student centered approach, their attitude toward physics might be positively affected (Erdemir, 2009). Udousoro (2000) and Popoola (2002) wrote that students tend to show more positive attitudes after been exposed to self learning strategy such as computer and text assisted programmed instruction, self learning device and self instructed problem based. Hunt, Haidet, Coverdale, and Richards (2003), noted favourable student attitude towards active learning methods. Adesoji (2008), Akınoğlu and Tandoğan (2007), concluded that students in the experimental group may develop more positive attitude towards science subjects after the treatment of problem-solving teaching. Similar results were obtained by Udousoro (2000) after using computer and text assisted programmed instruction and Popoola (2002) after exposing students to a self learning device. Interests are considered to be the most important motivational factors in learning and development. Abulude (2009), also reported that students' attitude towards chemistry have significant direct effect on students' achievement in the subject.

The students' attitude towards studying natural sciences have been the object of some studies and research began at an individual level, by independent researchers, by project teams, or by organizations. The studies and researches carried out have shown the fact that students acknowledge the importance of natural sciences for life and career but have also pointed out a significant drop in their interest in the study of these subjects (Osborne, Driver and Simon, 2003). Festus and Ekpete (2012) reported that students' performance in chemistry showed that the students still possess low attitudes towards problem-solving. Machina and Gokhley (2009) were of the view that "maintaining the levels of positive attitude towards science in early years is easier than transforming the negative attitude to positive attitude in the following years". As a result of these conflicting reports on students' problem-solving attitude and achievement, therefore the study investigated the variables and found how it can be improved positively.

2.7 Achievement in Science and Practical Chemistry

Science and Technology are interwoven and at the same time independent. The Oxford Advanced Learner's Dictionary defines science as the knowledge about the structure and behaviour of the natural and physical world, based on facts that you can prove for example by experiments pg 1307. It defines Technology as scientific knowledge used in practical ways in industry pg 1520. These definitions show that science provides knowledge while technology provides the way of using this knowledge. This shows that science is the foundation of technology.

According to research the major goal of science education is the production of citizens who are scientifically and technologically literate with a high competence for rational thought and action. This requires that pupils understand the challenge posed by scientific and technological activities and the value of using a scientific approach to solve their problems as well as to understand their world and universe. Emphasis is on methods of science teaching which have to do with students' problem-solving skills in order to meet the present scientific and technological trend (Bilgin, 2005). There is evidence to show that students generally have problem-solving difficulties and misconceptions in chemistry (Adesoji, 2008; WAEC, 2007, 2005). This explains why there have been many researchers probing into students' problem-solving difficulties and misconceptions in various aspects of science.

The importance of science cannot be over emphasized, with its presence in agriculture, certain remote possibilities have become realities or at least very probable by the application of bio-technology and genetic engineering; food production has now increased by an enormous factor and man is potentially capable of banishing hunger from the surface of the earth population explosion notwithstanding. The development in computer technology has brought about what is called "Second degree" industrial revolution. Man now has in power the wherewithal to solve easily most of the problems of his material existence by the application of advanced science and technology (Ananza, 2013). Science is knowledge based and process based correspondingly, science education entails the intellectual activities that are concerned with teaching of science to lead students to know, understand and practice the scientific methods in their daily interactions with nature and natural phenomena. Science is basically about becoming aware, exploring, understanding and exercising some degree of control over the environment through the senses, and personal exploration. It is in part a body of knowledge about nature and in part the method or methods of generating knowledge about nature (Dogru, 2008 and Erinosho, 2003).

In a world based on science and technology, it is science education that determines the level of prosperity, welfare and security of the people. The universal acceptance of the above position is responsible for the pride of place that is accorded science education in the school curricula of various nations of the world. In Nigeria, the Federal and State governments seem to have realized that real development of their human and material resources is synonymous with the development of science and technology as stated in the National Policy on Education (FRN, 2004). The adoption of the 6-3-3-4 system of education, the establishment of several State and Federal Polytechnics, Universities of Agriculture, Universities of Science and Technology, Ministry of Science and Technology, and the adoption of a 60:40 ratio of students' admission into higher institutions to pursue courses in "Science" and "Arts" respectively, all tend to show that the nation has realized the importance of science to a modern state (Olatoye, 2002).

Achievement is one of the most important indicators in which policy makers in education are interested. The Oxford Advanced Learner's dictionary defines achievement as the act of a thing done successfully especially with effort and skill pg 11. The researcher is of the opinion that achievement is the end product of a learning experience. Achievement tests are given after formal instruction to find out how much a person has learnt so as to predict how well he will learn additional material of similar nature or to indicate whether the person has the necessary skills or knowledge for future success in a course of study or trade. In spite of this realization and the concomitant effort at its operationalization, it is known that interest, enrolment and achievement in science subjects, have continued to decline in the country (Ogunleye, 2008; Olatoye and Afuwape, 2003).

Chemistry is a very important subject in the field of science. Its unique position and importance may be better appreciated when it is realized that it is necessary for the understanding and advancement of other sciences and technologies. Probably, no other science subject has such a wide applicability. Considerable knowledge of chemistry is required in areas such as Agriculture, Soil science, Geology, Biology, Agronomy, Biochemistry, Forestry, Medicine, Dentistry, Veterinary medicine, Metallurgy, Mineralogy, Pharmacy, Food technology, Textiles and Clothing Materials science, Chemical engineering, Industrial electrical/electronic e.t.c. In the context of Science education, Chemistry has been identified as a very important subject whose importance in the scientific and technological development of any nation has been widely reported (Adesoji and Olatunbosun, 2008). It is one of the three subjects classified as the natural science (chemistry, physics and biology) for the Senior Secondary School (SSS) curriculum in Nigeria (FME, 2007). The curriculum is aimed at satisfying the chemistry requirements of the SSS programme in the National Policy on Education (FRN, 2004) has the following objectives;

- To facilitate transition in the use of scientific concepts and techniques acquired in basic science and technology with chemistry.
- To provide the students with basic knowledge in chemical concepts and principles through efficient selection of content and sequencing.
- To show chemistry in its interrelationship with other subjects.
- To show chemistry in its link with industry, everyday life, benefits and hazards and
- Provide a course which is complete for pupils not proceeding to higher education while it is at the same time a reasonably adequate foundation for post secondary chemistry course.

The topics are arranged into instructional units which are sequenced in spiral form with each unit treated in greater detail as the course progresses. Each unit is organized under the following headings: teaching topics, performance objectives, content, activities (teacher and students), teaching and learning materials and evaluation guide. The curriculum content resting on the practical and activity of the students is recommended to ensure that learners are provided with continuous experience in and skill of defining problems, recognizing assumptions, critical thinking, hypothesizing, observing, collecting and recording data, testing and evaluating evidence, manipulating variables, generalizing and applying generalizations. In line with the current trends in chemical education chemistry teaching should focus on the following broad aims:

- To stress principles and unifying concepts of chemistry without demanding memorization by pupils of a vast amount of factual information and
- To develop skills in investigating problems based on an understanding of practical work. (WAEC Syllabus, 2013- 2015).

Problem-solving is a major characteristic of basic sciences and its neglect could hinder students' learning outcome in science, chemistry inclusive. As one of the basic sciences, chemistry is characterized by problem-solving. The fact that the subject is in part mathematical in nature has made the subject more problem based (Mahalingam *et al*., 2008; Inyang and Ekpeyong, 2000). According to Babatunde (2001), teachers hardly engage pupils in problem- solving activities which is capable of promoting their ability to think. He concluded that the achievement of secondary school students in solving word problems in mathematics and physical sciences could be enhanced through such activities. Sule (2000) showed that mere is a significant relationship between the students' scores in attitude test and the teacher made diagnostic test.

The importance and role of attitude towards science can be recognized from the researches' findings showing positive relationship of attitude towards science and achievement, and students with more positive attitude towards science has sustainable learning, and also want to continue with those subjects they enjoy (Craker, 2006). Detection of students' attitudes can have a contribution to make interests and curiosity lively and increase the success of students. Studies have revealed that teaching methods influence on students' attitudes towards science and predict achievement. However, a positive attitude toward science can be developed through hands-on activities and other methods of instruction that excite students and encourage them to learn like problem solving teaching strategies (Erdemir, 2009; Adesoji, 2008; Gok and Sılay, 2008). Gok and Sılay (2010) were of the view that "One of the fundamental achievements of education is to enable students to use their knowledge in problem-solving"

A number of other studies on the relationship between students' attitude and learning outcome in science show that science educators have not reached a consensus opinion on the relationship between the two variables. One school of thought indicates a direct relationship between attitude and performance in science (Olatoye, 2002), while Adesoji and Fasuyi (2001) did not establish such relationship. Festus and Ekpete (2012) wrote that in spite of the 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 poor performance and low enrolment. In his own contribution Akubuiro (2004), found that students' attitude towards science subjects maybe positively related to their performance in these subjects. He also discovered that attitude contributed substantially more than other variables in predicting achievement. Gok and Sılay (2008) worked on the effects of directive and non-directive problem-solving on attitudes and achievement of students in a developmental science course; the result is that attitude becomes more positive after instruction.

Sule (2000) wrote that reports of studies carried out in America on problem-solving attitude and achievement in mathematics revealed that certain elements of behaviour were manifested by learners in the process of solving mathematical problems. He went further that the ability of individuals to solve problems is to a large extent dependent on the attitude that the individual learner develops towards problem-solving. He also reported that in the Nigerian context the result of a research work conducted on problem-solving attitudes and students' corresponding achievement in mathematics shows little evidence of correlation between students' attitudes and their ability to solve word problems in mathematics. While he found that there is a significant relationship between problem-solving attitudes of senior secondary school students and their level of academic achievement in the teacher made test in mathematics. Due to these controversial results the study looked into the influence of the problem-solving approaches on achievement in practical chemistry.

2.8 Chemistry Process Skills and Students' Attitude to Practical Chemistry

The science process skills referred to as chemistry process skills in this study are the foundation of problem-solving in science. These skills are separated into two categories namely basic and integrated. The basic science process skills are: Observing, Classifying, Measuring, Communicating, Inferring and Predicting. The integrated science process skills include: Experimenting and Interpreting data. There is a hierarchical relationship between the two broad skills the acquisition of basic skills is a pre-requisite for the acquisition of integrated skills (Wetzel, 2008).

Basic skills

- Observing- Using the five senses to find out information about objects: an object's characteristics, properties, similarities and other identification features.
- Classifying-The process of grouping and ordering objects.
- Measuring- Comparing unknown quantities with known quantities such as: standard and non standard unit of measure.

- Communicating- Using multimedia, written, graphs, images, or other means to share findings.
- Inferring- forming ideas to explain observations.
- Predicting- Developing an assumption of the expected outcome.

Integrated skills

- Experimenting- Carrying out an investigation.
- Interpreting data- Analyzing the results of an investigation.

This study concentrated on most of the basic skills such as Observing, Measuring, Inferring and Predicting and on the integrated skills- Experimenting and Interpreting data.

Problem-solving in chemistry is a scientific process of providing an answer to a solution of a given problem situation in chemistry. Ishola (2000), wrote that problem-solving in chemistry is an obstacle or barrier in the path from problem to solution. The barrier is lack of problem-solving skill which could help in solving the problem, for example a problem which requires students to determine the concentration of a particular solution in quantitative or volumetric analysis, requires the students to determine the mole ratio which is the number of moles acid, that is combining with the number of moles of base, the molar mass of the unknown solution and the expression which relates concentration to molar mass. Therefore problem-solving is a way of removing the barrier in the path of problem to solution. Discussions on problem-solving behaviour of students in chemistry seem to support the view that the difficulty which the students encounter in problem-solving is not merely due to lack of chemical knowledge, it is often with processes involved in the application of knowledge (Raimi and Fabiyi, 2008).

Several factors influence the abilities in solving problems, from the nature of the problem, to the learner's developmental level and their knowledge base, to motivation and problem-solving skills (Reid and Yang, 2002). Normah and Salleh (2006) discovered that students who can successfully solve a problem possess good reading skills, have the ability to compare and contrast various cases, can identify important aspects of a problem, can estimate and create analogies and attempt trying various strategies. "Problem-solving involves a higher level of information processing than the other functions and mobilizes perception, attention and memory in a concerted effort to reach a higher goal". Due to the importance of problem-solving skills (chemistry process skills) which are needed in order to meet the present scientific and technological trend, the possession of these skills and the relationship with students' attitude to practical chemistry were examined.

2.9 Chemistry Process skills and achievement in Practical Chemistry

Science deals with an exploration into the known and unknown world to gather information, acquire knowledge, skills and attitudes necessary for individuals to live effectively in the society. For students to function as scientists, they must be trained in the basic skills and processes of science, including observing, measuring, classifying, identifying problems, collecting, analyzing and interpreting data, formulating hypothesis, experimentation, etc (Dogru, 2008). An examination of some science curricula currently in use in schools, show an emphasis on students involvement in science through practical activity in the classroom. This can be seen in the Nigerian Secondary School Science Projects (NSSP) in the different science subjects at the Senior Secondary School level. These offer a wide range of practical activities aimed at involving students in the processes of science, so that the theoretical concepts to which they are exposed are given meaning when students see their application in real life situations (Ige, 2003). Erinosho (2003) described laboratory work as often being dull and teacher directed and so students often fail to relate the laboratory work to other aspects of their learning. She went further that practical or laboratory work could be made more interesting and effective if students are involved in problem-solving, especially if problems have relevance to their daily lives.

Many surveys indicated that most of students are not able enough in acquiring knowledge independently and in the application of this knowledge to solve everyday life problems. Practical work is motivational that may be linked to the promotion of interest and social skills, involving students in the application of substantive knowledge and also in the development of experimental skills. This implies that students must be helped to have a sound knowledge base in the major disciplines of science, in the collection, validation, representation and interpretation of evidence, as well as in the development of scientific attitude. More importantly they need to be exposed to activities that will enable them effectively harness their experiences for use in solving problems confronting them on a daily basis (Adesoji, 2008). Ige, (2003) observed that in many secondary schools in Nigeria teachers give separate lessons for theory and for practical. Students do not have enough opportunities to effectively apply their theoretical knowledge of science concepts in practical situations. Nwagbo and Chukelu, (2012); Akale and Usman (1993) noted that there is the tendency of teachers to muddle up practical work with theory to the extent that practical work distorts students theoretical understanding of science content. They suggested that teachers should strive to help students integrate theory with the experience they gain in practical work to enable them achieve a better understanding of science. That the role played by the science teachers in practical work is crucial to the experience that students receive. Whether he assumes the position of a dispenser of knowledge while students observe and memorize facts or if he is a ‘guide to learning’ so student can learn by doing. The mental processes and skills associated with science can only be acquired and developed when students actually participate in science instruction through practical experience. Usman (2000) showed that lack of adequate materials for practical activities is one of the reasons claimed by teachers for the constant use of traditional lecture method in teaching science. The use of problem-solving approach proffers advantages for science classes as it specifies in unmistakable terms what the students are expected to do at each stage. It also helps students apply their theoretical knowledge of science concepts and skills to practical problems (Ige 2003). Senocak, Taskesenligil, and Sozbilir, (2007) found that there is probably a statistically significant difference between the problem based learning and conventional groups in terms of their attitude towards chemistry, skill development and conceptual understanding. InceAka and Aydogdu (2010) also discovered that problem-solving skills probably had significant effect on achievement. Akubuilo (2004) stated that problem-solving instructional strategies, which may result in improved cognitive development, acquisition of skills and retention of subject learnt could lead to improved attitude towards solving life problems.

Numerous teaching methods can be used for problem-solving strategies. Therefore the investigation of students' attitude, behaviours, problem-solving knowledge and skills becomes important while solving a problem (Erdemir, 2009). Lack of problem-solving skills by the students was described by Reid and Yang (2002) as non-use of the different stages of problem-solving. That the teaching of problem-solving skills should be an integral part of science education. Also that to an extent, every problem requires the individual to possess information and to process this information in order to progress from a state of having a problem to the state of having a solution. Students do not have an organized problem-solving strategy and therefore find problem-solving difficult generally. According to Ige (2001) and Adesoji (2008), clearer understanding of what constitute problem-solving skills would enhance the design of specific instructional activities and materials necessary for the development of these skills. They found that students had difficulty in defining problem in relation to relevant data for solving problems. They explained further that, a number of these students who had difficulties at the first two stages, lack organizational skills and that affected their overall performance. They stressed the need to train students to develop appropriate skills for solving problems using the appropriate problem-solving model.

Many tasks performed in professional and daily life require problem-solving abilities. These tasks could range from designing a product, solving management problem, analyzing a scientific problem like discharge of poisonous gases or predicting flooding in an ecological zone to opening a door with a jammed lock. Therefore incorporating problem-solving in science learning may be regarded as a step in the right direction as it would equip students with relevant knowledge, skills and experience. Suggestions from research are that instructional methods should take into account the general strategies and methods of problem- solving, thus providing a tool to increase reasoning skills in the problem solver. Life is, in essence a continuous process of problem-solving and selection from available and/or created options. Nevertheless, problem-solving abilities or decision making capacities are valuable and precious skills not only in academia, but also in the world of business and industry and in daily living. Furthermore, in science these skills play an important role in the acquisition and organization of knowledge in a meaningful way (Cardellini, 2006). Due to the importance of chemistry process skills which are needed in order to meet the present scientific and technological trend, the possession of these skills and the relationship with achievement were examined.

2.10 Class Size and Problem-Solving Attitude in Practical Chemistry

Class size may be broadly defined as the relative amount of instructional service in terms of professional personnel, that is brought about to bear upon the educational task (Ogundipe, 2004). He classified it into three as follows:

(a) A "small" class containing 5 to 30 students.
(b) A "medium" class containing 31 to 90 students
(c) A "large" class containing 90 plus students.

For this study class size is classified into two:

(a) A "small" class size containing 40 students and below,
(b) A "large" class size containing 41 students and above according to the National Policy on Education (FRN, 2004).

Obviously, there are questions about the generalizability of individual case descriptions. The characteristics of the children in the school, the composition of the class and the qualities of the teacher and the school are all important. The fore going shows the obvious potential in smaller classes for more teaching support and focused teaching. Professional judgment of teachers is that smaller classes allow more effective and flexible teaching and the potential for more effective learning. However, there is vigorous debate over the educational consequences of class size differences. In the United States, the debate centered on the efficacy and cost effectiveness of initiative to reduce class size. A worry in the United Kingdom has been that classes are too large and that teaching, learning and children's educational progress can suffer (Rivikin, Hanushek and Kain, 2000).

Blatchford, Moriaty and Martin (2003) gave account of a survey of teachers' and head teachers' views showed that practitioners believed that large class size affected teaching and learning and are particularly aware that larger classes could have an adverse effect on amount of teachers' attention. They found that smaller classes resulted in greater teacher knowledge of pupils, frequency of one to one contacts between teachers and pupils, variety of activities, adaptation of teaching to individual pupils and opportunities to talk to parents, other studies reported more individual teaching attention and more feedback. They discovered that monitoring, checking understanding and offering appropriate feedback to individual children is more difficult in a large class, also learning of basic skills suffer in large classes. That teachers of large classes are under stress and worn out spending many hours outside their contact time marking, the teacher child interactions are also concerned with management activities, and quelling rising noise levels. They went further that the behaviour of the pupils could be strained this is probably related to the limited amount of space that the pupils had to move in. Also grouping pupils by ability are inevitably large and included a wide range of ability. However, in direct contrast to teachers' views, Blatchford et al (2003) reported no statistically significant differences between class sizes for most teachers' activities.

Class size has become a phenomenon often mentioned in the educational literature as an influence on pupils' feelings and achievement, on administration quality and school budgets. It is almost an administrative decision over which teachers have little or no control (Arias and Walker, 2004 and Adeyela, 2000). Ogundipe (2004) showed that reduced class size with a 1:15 teacher-student ratio shows positive results on reading and mathematics. That teaching may affect pupils' achievements and learning in a causal way. Also class size can be seen as one contextual influence on classroom life, which plays a part in the nature of interactions between teachers and pupils. Again there is immense practical and financial difficulty in setting up large-scale experimental studies of large class size. Blatchford, Bnines, Kutnick and Martin (2001) also wrote that the advantages of large class size include decreased instructor costs, availability of resources and standardization of learning experience. That the judgment and experience of many practicing teachers is that, other things being equal, teaching and learning are likely to be improved in smaller classes. But the evidence from research is not clear-cut, and some of it even suggested that although teachers may feel their teaching has benefited in small classes, their feeling is not supported by observational data. On logical and common sense grounds, it seems likely that the greater the number of children in a class, the more times the teachers will spend on procedural matters and conversely, the less time the teachers will spend on instruction (Hanushek, 2003).

Kokkelenberg, Dillon and Sean (2005) showed that class size is the primary environmental variable teachers must contend with when developing effective teaching strategies. They argued that while class size may not be significant in courses best suited for lecture style learning, courses geared toward promoting critical thinking and advanced problem-solving are probably best taught in a smaller classroom environment. In a review summary Fleming, Toutant and Raptis (2002), wrote that an increase in class size does not necessarily lead to a decrease in level of academic achievement. Likewise, a decrease in class size does not guarantee an improvement in the social environment of learning, more important is what the teacher does with the opportunities provided by the size of the class, that large classes versus small classes have little or no effect on students' performance. Due to all these different findings, opinions and observations, there is the need to further research into the effect of class size on problem-solving attitude of the students in practical chemistry.

2.11 Class Size and Achievement in Practical Chemistry

Class size refers to an educational tool that can be used to describe the average number of students per class in a school (Adeyemi, 2008). Some researchers such as Babatunde and Olanrewaju (2014) and Deutsch (2003) emphasized that class size is an important factor in the teaching and learning process and that it has effect on students' achievement. That the influence of class size on academic performance has been the focus of both academic and policy debate. Numerous studies show that there has been a sharp decline in the academic performance of various levels of our educational system in Nigeria, and the decline has been attributed largely to the poor condition in educational institutions in the country. Worse still there has been an upsurge in the number of both community and privately owned secondary schools, accompanied with a gross lack of modern instructional technologies, poor physical classroom conditions and lack of adequate training programme for teachers. The issue of quality in science education goes beyond subject matter content but include classroom learning environment and school factors which have been speculated to influence achievement in science (chemistry inclusive) (Obayan, 2003; Olatunbosun, 2006).

Parents and educators universally identified small classes as a desirable attribute of successful school systems and class size reduction initiatives have been implemented widely. Despite this and decades of study, researchers remain divided on whether smaller classes actually have positive effects on students' outcome and/or whether the magnitude of the effect justifies the high cost of implementing class size reductions. In fact, a larger debate focuses on whether increasing resources to schools in any way improves students' outcome. These discussions are being carried out throughout the world, with some different frame works between developed and developing countries. In developed countries where access to primary and secondary education is essentially universal but the quality is varied, researchers are concerned with identifying specific treatments to improve students' outcomes, such as reduced class size, increasing teachers' salaries, or expanding teacher education. Developing countries are often still dealing with the tradeoff between increasing access to education and improving the quality of existing education. Improving quality in this context can mean providing textbooks and adequate facilities, more fundamental needs than are the focus in the developed world (Averest and Mclennan, 2011). To many parents, educators and policy makers, smaller classes are an apparently full-proof prescription for improving students' performance. That is fewer students means more individual attention from the teachers, calmer classrooms and consequently, higher test scores (Fall, 2003). The larger the class, the less time teachers spend on instruction, and the more time they spend on discipline or keeping order (Deutsch, 2003). The largest difference in achievement between students is that between students in different classes (Ken, 2001).

Nye, Hedges and Konstantopowlos (2000), discovered that smaller classes (below 20) have positive effects on pupils academic performance. Blatchford et al., (2003) pointed out that small classes can encourage aspects of teaching that are the same as those identified in research on effective teaching (e.g immediate feedback, sustaining purposeful interactions) linked with the promotion of pupils achievement. They explained that the connection may not necessarily follow, that small classes will not make a bad teacher better, but small classes seem likely to make it easier for teachers to be effective. Averest and Mclennan, (2011) reported a positive and significant effect of class size on children test scores for United State of America. They also reported a positive relationship between class size and test scores for Israel. For Britain they reported that class size is not significant in explaining students' performance. In addition they reported that time series evidence suggests that class size reductions in the United States over the last three decades have not led to improvements in students' performance. Woessman and West (2002), found significant effect of class size on mathematics or science test scores. They found significant benefits to smaller classes for mathematics in France and on Iceland and for science in Greece and Spain. It is one of the environmental contextual factor that will influence teachers and pupils in a number of ways (Blatchford et al, 2003). While Averest and Mclennan (2011) concluded that Senior Secondary Students in small sized classes show higher achievement in chemistry relative to their colleagues in large sized classes.

Hanushek (2003) wrote that there is no significant relationship between teacher-pupil ratio and student outcomes in developed countries. His analysis of studies involving developing countries shows that almost half of the studies found no significant effect and the studies that are significant are divided equally between positive and negative findings. He concluded that the weight of the evidence showed no consistent positive effect of reducing class size on students' outcome. Woessmann and West (2002) and Pong and Pallas (2001) observed positive and often significant class size effects in several different countries. Kokkelenberg et al., (2005) presented a theoretical model suggesting that the functional form of the relationship between class size and student achievement should be negatively sloped and concave. Even though there is now strong evidence that smaller class size may improve student performance, at least in some circumstances, and using common methodologists to test the data. The debate continues in particular the economists point out the need to weigh the cost of achieving smaller classes versus the costs of improving student achievement by other means (Hanushek and Luque, 2003).

There are significant disadvantages of large classes which include strained impersonal relations between students and the instructor, limited range of teaching methods, discomfort among instructors teaching large classes (Stanley and Porter, 2002). Extant research on the relationship between class size and students performance has identified conflicting results (Toth and Montagna, 2002). The results of some studies showed no significant relationship between class size and student performance according to Carpenter (2006), while other studies favour small class environments, the results vary based on the criteria used to gauge students' performance as well as the class size measure. When traditional achievement tests are used, small classes may provide no advantage over large classes. However if additional performance criteria are used (e.g. long term retention, problem-solving skills), it appears that small classes hold an advantage (Aria and Walker, 2004). Blatchford et al., (2003) concluded that there is a lack of coherent theories by which to guide and interpret empirical work on class size effects and with which to make new predictions. The literature on class size, composition and students' achievement is broad, diverse, diffuse and generally unwieldy. As one researcher has described it that the outcomes of the research effort (into the connection between class six and educational attainments) have been conflicting, inconclusive and disappointingly meager (Fleming, et al 2002).

Afolabi (2002) investigated school factors and learner variables as correlates of senior secondary physics achievement in Ibadan found no significant relationship among class size and students' learning outcomes. On the other hand, Adeyemi (2008) worked on the influence of class size on the quality of output in senior secondary schools in Ekiti State, Nigeria found that schools having an average class size of ≤35 obtained better results than those having > 35. On investigating the effect of class size on students' achievement: evidence from Bangladesh, Asadullah (2005) concluded that reduction in class size in secondary grades is not efficient in a developing country like Bangladesh. Thus the divergent view on the effect of class size on achievement continues. Based on the various controversial results of findings on the effects of class size on students achievement in science subjects especially chemistry, this study examined the relationship between class size and students' achievement in practical chemistry.

2.12 Appraisal of Literature Reviewed

Researches show that in order to increase the level of attitude and success in science education, new teaching methods and technology need to be implemented in science education **(**Adesoji, 2008; Goner and Basaran 2008). Problem-solving is one of the most important issues in teaching and learning. The role of problem-solving in science is indispensable. It is an integral part of science. Science itself is a problem-solving subject. It is a subject that revolves around finding one solution or the other to some problems. Problem-solving should be the centre of instruction, and the way it is practiced must change, it should be a part of an active learning of the instructional process. When students know all the relevant facts and principles necessary for the solution of a problem, they may be unable to solve it because they lack any systematic strategy for guiding them to apply such facts and principles (Gok and Silay, 2010). The notion of problem-solving which is sometimes described as a core skill has received much attention in the literature of science education. Unfortunately there is considerable diversity in seeking to describe what problem-solving actually is, ranging from descriptions of analytical procedures to statements like 'What you do when you don't know what to do' (Rusbult, 2008).

Many tasks performed in professional and daily life require problem-solving abilities. These tasks could range from designing a product, solving management problem, analyzing a scientific problem like discharge of poisonous gases or predicting flooding in an ecological zone to opening a door with a jammed lock. Therefore incorporating problem-solving in science learning may be regarded as a step in the right direction as it would equip students with relevant knowledge, skills and experience. Suggestions from research are that instructional methods should take into account the general strategies and methods of problem-solving, thus providing a tool to increase reasoning skills in the problem solver. Life is, in essence a continuous process of problem-solving and selection from available and/or created options. Nevertheless, problem-solving abilities or decision making capacities are valuable and precious skills not only in academia, but also in the world of business and industry and in daily living. Furthermore, in science these skills play an important role in the acquisition and organization of knowledge in a meaningful way (Cardellini, 2006). This shows the importance of chemistry process skills which is acquired during the performance of practical. Reports from research showed that students performed poorly in practical chemistry and they had poor quantitative skills. Therefore the research into chemistry process skills formed the basis for this study and it was discovered that they had significant effect on achievement in practical chemistry.

Few literature relating to problem-solving models in chemistry is available (Selvaratnam–Frazer, 1982). Some problem-solving models were designed to solve practical problems in science in which students were exposed to practical activities or learning tasks (West, 1992; Ige, 2003), while few were designed to help students develop laboratory skills (Onwioduokit, 1989; Ikitde, 1994). Cardellini (2006) discovered that many models have been used in teaching but still the performance of the students is still low. This necessitated the need for the researcher to develop a model that could be used to meet the needs, demands and complexities of practical, experimental and theoretical problem-solving in science.

Reviewed studies show that the achievement tests scores of students are used as a measure of not only the students' achievement but also the teachers' achievement, performance and effectiveness (Hudson, 2007). It was discovered from this study that treatments had significant effects on students' achievement in practical chemistry while Hands-on and Minds-on Problem-Solving Model had the highest mean score. Researchers such as Joshua., *et al* (2006) and Berk (2005) were of the opinion that test based students' achievement gains have predictive power but provide little insight into both the teachers and the students' strengths and weaknesses, except factors such as students' attitude, classroom environment such as class size, teachers' qualification. This is the reason why this study looked into these factors and the researcher made sure the teachers in the researched schools are professionally qualified.

The attitude of a learner towards science would determine the measure of the learners' attractiveness or repulsiveness to science. This will invariably influence the learners' choice and even achievement in that subject (Gonen and Basaran (2008); Normah and Salleh, 2006). Adesoji (2008) maintained that problem-solving strategy is probably a basic means of changing students' attitude towards science, that the effect of solving problem on a student's attitude toward science is incredibly important because problem-solving requires patience, persistence, perseverance and willingness to accept risks. It was discovered from this study that treatments had no significant effect on students' attitude to practical chemistry. This can be explained by the findings of Machina and Gokhley (2009) that "maintaining the levels of positive attitude towards science in early years is easier than transforming the negative attitude to positive attitude in the following years". Festus and Ekpete (2012) wrote that recent reports on students' performance in chemistry show that the students still possess low attitudes towards problem-solving in chemistry.

Class size is one environmental contextual factor that will influence teachers and pupils in a number of ways (Blatchford et al., 2003). The literature on class size, composition and students' achievement is broad, diverse, diffuse and generally unwieldy. As one researcher describes it as the outcomes of the research effort have been conflicting, inconclusive and disappointingly meager (Fleming et al., 2002). Parents and educators almost universally identify small classes as a desirable attribute of successful school systems and class size reduction initiatives have been implemented widely. Despite this and decades of study, researchers remain divided on whether smaller classes actually have positive effects on students' outcome and/ or whether the magnitude of the effect justifies the high cost of implementing class size reductions.

A larger debate focuses on whether increasing resources to schools in any way improves students' outcome. This discussion is being carried out throughout the world, with some different frame works between developed and developing countries. In developed countries where access to primary and secondary education is essentially universal but the quality is varied, researchers are concerned with identifying specific treatments to improve students' outcomes, such as reduced class size, increasing teachers' salaries, or expanding teacher education. Developing countries are often still dealing with the tradeoff between increasing access to education and improving the quality of existing education. Improving quality in this context can mean providing textbooks and adequate facilities, more fundamental needs than are the focus in the developed world (Averest, and Mclennan, 2011).

Due to these the researcher developed a model Hands-on and Minds-on Problem-Solving Model (HAMPSOM) which combines both theoretical and practical aspects of science as opposed to the separate theoretical and practical models found in literature, incorporating intensive theoretical background and teacher guided discovery learning. This study examined the extent to which the models (HAMPSOM) and (LAPSOM) using the instructional guides improved students' attitude to and achievement in practical chemistry. It further determined the moderating effects of level of possession of chemistry process skills by the students and class size.

CHAPTER THREE

3.0 METHODOLOGY

This chapter deals with Research Design, Population of the Study, Sample and Sampling Techniques, Instrument and Instrumentation, Data Collection and Data Analysis Procedure.

3.1 Research Design

A quasi experimental design was used for this study. A 3x2x2 non randomised control group pretest and posttest design was adopted.

The layout of the research design is as follows:

E_1 O_1 X_1 O_2
E_2 O_1 X_2 O_2
C O_1 X_3 O_2

where

E_1 represents experimental group 1
E_2 represents experimental group 2
C represents control group
O_1 represents pretest scores of the experimental and control groups
O_2 represents posttest scores of the experimental and control groups
X_1 represents experimental treatment with Laboratory Problem-Solving Model (LAPSOM) instructional guide
X_2 represents experimental treatment with Hands-on and Minds-on Problem-Solving Model (HAMPSOM) instructional guide
X_3 represents conventional method of teaching for the Control group

3.2 Factorial Design

The 3x2x2 non randomised factorial design is shown below

Table 3.1: 3x2x2 Factorial Matrix

TREATMENT	CLASS SIZE	LEVEL OF SKILL POSSESSION	
		H	L
E_1	L		
	S		
E_2	L		
	S		
C	L		
	S		

E_1 represents experimental treatment with Laboratory Problem-Solving Model (LAPSOM) instructional guide.

E_2 represents experimental treatment with Hands-on and Minds-on Problem-Solving Model (HAMPSOM) instructional guide.

C represents teaching with the conventional method as control.

S represents small class size with number of students 40 and below.

L represents large class size with number of students 41 and above.

H represents students with high scores above 50th percentile.

L represents students with low scores below 50th percentile.

3.3 Variables of the Study

Independent Variables Teaching at three levels.

a Laboratory Problem-Solving Model (LAPSOM)

b Hands-on and Minds-on Problem-Solving Model (HAMPSOM)

c Conventional Method as control

Intervening (Moderator) Variables.

a Chemistry Process Skills

b Class size

Dependent Variables.

a Students Attitude to Practical Chemistry

b Achievement in Chemistry

3.4 Population.

This comprised of intact class of S.S 2 chemistry students from three educational zones in nine local government areas and nine public schools in Oyo state as shown in Table 3.3. Table 3.2 shows the Educational Zones with the number of Local Government Areas and number of Public Senior Schools in each zone.

Table 3.2: The distribution of Public Senior Secondary Schools across the Eight Educational Zones in Oyo State.

Educational Zones	**No. of Local Govt. Areas**	**No of Public Senior Secondary Schools**
Ibadan Municipal	5	81
Ibadan Less City	6	110
Ibarapa	3	19
Ogbomoso	5	64
Oyo	4	38
Saki	3	33
Irepo	3	14
Kajola	4	50
Total 8	**33**	**409**

Source: Statistics Department, Ministry of Education, Oyo State. (2012)

Table 3.3: Sampling Distribution

	Educational Zone	Local Government	Selected Local government	No. of Schools chosen	No. of Students
1	Ibadan Municipal	Ibadan North Ibadan N East Ibadan S West Ibadan S East Ibadan N West	Ibadan North -- Ibadan S West -- Ibadan N West	1 -- 1 -- 1	IntactClass(Expt1) (58) -- IntactClass(Expt2) (65) -- IntactClassControl (33)
	Ibadan Less city	Lagelu Egbeda Akinyele Ona-Ara Oluyole	Lagelu -- Akinyele -- Oluyole	1 -- 1 -- 1	IntactClass(Expt1) (36) -- IntactClass(Expt2) (49) -- IntactClassControl (31)
3	Oyo	Afijio Oyo West Atiba Oyo East	Afijio -- Atiba Oyo East	1 -- 1 1	IntactClass(Expt1) (65) -- IntactClass(Expt2) (40) IntactClass (Control) (62)
	TOTAL 03	14	09	09	5 Large C.S = 299 4 Small C.S =140 Total = 439

3.5 Sampling Technique and Sample

School Sample

Multi-Stage sampling technique was used to select schools that participated in the study. At the first stage, the names, number of local government areas and the number, names of secondary schools in the eight educational zones, were obtained from the Ministry of Education. Also schools approved by the West African Examinations Council (WAEC), to register and prepare students for the West African Senior School Certificate Examination (WASSCE) in chemistry for at least five academic sessions were obtained.

The second stage involved the sampling of three educational zones and nine local government areas based on their geographical location, so as to avoid experimental contamination.

The third stage involved stratification of schools from the list of eligible schools in the first stage in the nine local government areas. To ensure comparability of schools, each school eligible for selection was based on:

(1) Availability of the basic chemistry apparatus needed for the study, by administering the Laboratory Inventory Check List (LICL) developed by the researcher for the teachers. (See APPENDIX VII).

(2) Availability of a professionally qualified chemistry teacher for at least three academic sessions.

(3) Willingness of the principal to allow the research to be carried out in the school.

(4) Cooperation of the chemistry teacher and willingness to participate in the research.

The fourth stage involved the selection of nine schools (sample) which was done by stratified sampling of the eligible schools on the basis of geographical location. The study samples were reasonably spaced from each other, and no school had more than one treatment condition so as to avoid experimental contamination. The three schools in each local government area were randomly assigned the two treatment conditions and control.

Students' Sample

These were all the S.S 2 students offering chemistry as one of their WASSCE subjects in the nine schools. Since classes in Senior Secondary Schools (S.S.S) in Oyo state were grouped into Science, Art and Commercial classes. In each of the selected schools an intact class of chemistry students in the science class with a total 439 students in the nine schools participated in the study. This is because it is only the science students that offer chemistry.

3.6 Instrumentation

Three instruments were used in this study. These are:

(1) Chemistry Achievement Tests. (CAT)

(2) Students’ Attitude to Practical Chemistry Scale. (SAPCS)

(3) Chemistry Process Skills Rating Scale (CPSRS)

Three Stimulus Instruments were used. These are:

(1) Laboratory Problem-Solving Model (LAPSOM) Instructional Guide.

(2) Hands-on and Minds-on Problem-Solving Model (HAMPSOM) Instructional Guide

(3) Conventional Method Instructional Guide as control.

(1) Chemistry Achievement Test. (CAT)

This is a 70-multiple choice item with four options A to D. Students supplied the correct answer. The content validity was established using the scheme of work for chemistry by the Ministry of Education Oyo State to develop the items across the cognitive domain using Bloom's taxonomy. The table of specification of the selected items is shown in Table 3.4. The difficulty levels of the items were determined. Thirty items with difficulty level ranging between 0.5 and 0.6 were selected (APPENDIX V11). The test items were trial tested on 140 S.S 2 students in schools not taking part in the study in Ibadan North Local Government Area of Oyo State. In the scoring, each correct option selected attracted one mark while every wrong answer attracted zero mark. The answers are in APPENDIX V111. Kuder Richardson formula 20 (KR-20) was used to establish the internal consistency of the instrument, a reliability value of 0.79 was obtained for the test items.

Table 3.4: Table of Specification

CONTENTS	COGNITIVE LEVELS						
TOPICS	KNOWLEDGE	COMPREHENSION	APPLICATION	ANALYSIS	SYNTHESIS	EVALUATION	TOTAL
Nature of matter: physical and chemical changes, elements, compounds and mixtures. Determination of the empirical formula of Magnesium oxide.	3, 5, 7 (03) (10.0%)	9, 11 (02) (6.7%)	1, 2 4, 6 ,8, (05) (16.7%)				10 (33.3%)
Separation technique: sublimation, filtration, evaporation, separation funnel method.	17, 18, 19, 20, 21, 23, 24, 26, 27, 28, (10)(33.3%)		22, 25, 16,30 (4) (13.3%)	12, 13 (02) (6.7%)	29 (01) (3.3%)		17 (56.7%)
Volumetric analysis			15 (01) (3.3%)	10 (01) (3.3%)	14 (01) (3.3%)		03 (10.0%)
TOTAL	13 43.3%	02 6.7%	10 33.3%	03 10.0%	02 6.7%		30 100%

(2) Students' Attitude to Practical Chemistry Scale (SAPCS)

This is a thirty item instrument. It was developed by the researcher with a 4- point Likert response options of **Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD).** (See APPENDIX 1X). It is concerned with finding out students' attitude to problem-solving in chemistry. Two procedures were adopted in the establishment of the validity of the instrument. Two lecturers from the Institute of Education, University of Ibadan, assessed the instrument and found it satisfactory in terms of content, clarity of expression and purpose of study. The thirty items were trial tested on 140 S.S 2 science students in Ibadan North Local government area, a group similar to those whom it is intended but did not form part of the sample. The Cronbach alpha statistics was preferred because it measures internal consistency of items and also the construct validity. The scoring was based on Likert scale of measurement: Strongly Agree (4), Agree (3), Disagree (2), Strongly Disagree (1) for items on the scale indicating positive attitude to chemistry problem solving. Scoring was reversed for items indicating negative attitude. The maximum score obtainable for SAPCS was one hundred (100). In order to categorize the students, their scores were standardized. Grouping was

Below -1 Standard Deviation (S.D) = Low attitude.
Above +1 Standard Deviation = High attitude.

The reliability estimate using Cronbach alpha coefficient was found to be 0.85.

(3) Chemistry Process Skills Rating Scale (CPSRS)

This instrument was adapted from A Scale For The Assessment of Students' Chemistry Practical Skills In Secondary Schools by Njoku (1999). It is a 5-point rating scale (Very Poor, Poor, Fair, Good, Excellent) containing 8 scale skill categories. Among these skill categories 57 skill items called behaviour categories were unevenly distributed. The researcher used 7 scale skill categories and 39 skill items for this study. (See APPENDIX X1) The researcher re-validated the instrument using two schools that did not take part in the study. The validity of CPSRS was assessed and judged as adequate by experts based in chemistry teaching. The inter rater reliability of CPSRS was estimated as 0.78 using Scott Pie method.

$$\text{Scott Pie} = \frac{P_0 - P_e}{100 - P_e} \qquad \text{Where } P_O = 100 - (\%\ \text{Difference}), \qquad P_e = \frac{(\%\ \text{Average})^2}{100}$$

The ratings were: Very poor = 1, Poor = 2, Fair = 3, Good = 4, Excellent = 5.

3.7 Procedure for the Study

The following steps were adopted:

- An official letter of introduction of the researcher and the study was obtained to the principals of the selected schools from the Institute of Education, University of Ibadan. Ibadan.
- The principals concerned were met individually for dialogue on the purpose, procedure of the study and official permission was obtained.
- The chemistry teachers of the selected schools for the study were met and intimated with the objectives of the study they served as the research assistants throughout the study. They did the main teaching using the treatment assigned to their respective schools.
- The research assistants were trained based on the treatment assigned to their school and the use of the Chemistry Process Skill Rating Scale (CPSRS) for two weeks.
- The chemistry students were met and i discussed the need for their cooperation during the study.
- The pre test Students' Attitude to Practical Chemistry Scale (SAPCS) was administered to the students by the research assistants and the researcher monitored the administration of the test.
- The pre test Chemistry Achievement Test (CAT) was also administered to the students.
- The students were observed during titration of an acid (HCl) against a base (NaOH). They were observed individually by the research assistants in each of the schools, using Chemistry Process Skills Rating Scale (CPSRS) for the pretest.
- The students were exposed to the treatments by the research assistants in the selected schools and the researcher monitored the administration of the treatments, for six weeks.
- The post tests of both the SAPCS and CAT were administered to the students after the treatments.
- The students were observed during titration of an acid (HCl) against a base (NaOH). They were observed individually by the research assistants in each of the schools using the Chemistry Process Skills Rating Scale (CPSRS), for the posttest.

3.8 Treatment Procedure

This part was designed to operationally (operational phase) enable the teaching and learning of problem-solving in practical chemistry, it specified in clear terms what the teacher and the students are expected to do at each step of the process. The procedures for each of the two model instructional guides were followed as stated below for the two treatment groups.

Treatment Group 1: **Laboratory Problem-Solving Model (LAPSOM Operational Teaching and Learning of Problem Solving (Instructional Guide)** (See Appendix IA, IB, IC).

The teacher teaches the theory during a period and the students perform the experiment or the practical during another period, usually a double period. The students use the laboratory manual which is an extract from the instructional guide and contains only the steps that the students follow during the experiment prepared by the teacher. The teacher is present with the students as an observer.

Stage1- Recognize the Problem

Actions (a) Read carefully the laboratory manual. Identify the practical problem posed and recognize the apparatus provided. Check the soundness of the apparatus

(b) Write down the problem and sub-problems that require solution (a problem may be in the form of a statement or a question or the aim of an experiment).

(c) Read the instruction or question again; sketch a diagram of how you intend to arrange the apparatus to enable you solve the problem.

Stage2 (A) Recall background information

Actions (a) Write down known general principles and mathematical expressions that are necessary for solving the problem.

(b) List possible sources of error in solving the problem.

(c) Recognise independent and dependent variables in the problem as explained by the teacher during the theory period and note the relationship between them.

(d) Re-arrange the mathematical model or expression in a simple form, making the required quantity the subject of the expression.

Stage 2(B) Predict tentatively

Actions: (a) Predict the relationship between variables the nature of the graph and the intercept (if any)

(b) Predict the solution to the problem

Stage 2(C) Draw up table for data

Actions: In view of the anticipated solution to the problem, draw up a table for data, providing appropriate units.

Stage 3A: Experiment

Actions (a) read the questions again

(b) Together with the sketched diagram in stage 1 step c, set up the apparatus to solve the problem.

(c) Take precautions on the basis of the supposed errors

(d) Manipulate the independent variable to obtain the corresponding value of the dependent variable (where applicable). Repeat the process with at least four other different values of the independent variable. Write the values straight into the table already drawn in stage 2c above.

Stage3B: Predict from data

Actions: inspect the data obtained and make more realistic predictions based on the data to include:

(a)Nature of the graph

(b)Position and nature of intercept when the independent variable is zero, the dependent variable could have a value other than zero.

(c)Solution of all the problems

Stage 4: Analyze the data

4(A) Graph

Actions: (a) Note the smallest and the largest values of the dependent and independent variables respectively, the size of your graph paper and then choose appropriate scales. Plot the values on the graph paper.

(b) Draw the best straight line or curve through the points.

Stage 4(B) Calculations

Actions: (a) find the slope and /or the intercept from the graph and relate them to the mathematical expression given or derived.

(b) Calculate all required values using the mathematical expression and the plotted graph

Stage 5(A) Evaluate your solution

Actions: (a) find the average values of both dependent variables

(b) Substitute these values and those obtained from the graph into the mathematical expression derived or given.

(c) Solve the equation to see whether or not the two sides are equal.

Stage 5 B: Evaluate your experiment

Actions: (a) is your equation balanced? Why?

Write down the importance of the problem solved

(b) What can you conclude from the experiment (solution to the problem) and what do you think could be done to improve the solution to the problem?

In cases when the required solution was not obtained, the steps were reversed.

Students answer the questions at the end of each topic.

NOTE Some stages may be missing in some experiments that do not involve variation of variables and plotting of graph(s), which the teacher would have explained during the theory period.

Treatment Group 2: Hands-on and Minds-on Problem-Solving Model (HAMPSOM) Operational Teaching and Learning of Problem-Solving (Instructional Guide) (See Appendix IIA, IIB, IIC).

Both the teacher and the students are involved in performing the experiment and the practical. The teacher teaches the theory actively involving the students and guides them to perform experiment or practical during the same period. Incorporating the experiments and the practical into the theory lesson, there is no separate period for theory or performing experiments/ practical.

STEP 1A: Problem Perception.

a. The teacher writes the problem in form of a question or a statement

The students:

a. Read the problem statement or question carefully.

b. Think about it

c. Write down what you want to find out.

Teacher goes round to see what they have written.

STEP 1B: Acquiring Related Theory.

a. The teacher teaches the students the related theory

STEP 1C: Planning Experiment.

a. The teacher draws diagram

The students:

a. Write down the apparatus.

b. Select the apparatus.

The teacher supervises them, renders help where necessary

STEP 2A: Recalling Theory.

The students:

a. Write down the laws and the equations.

b. Write down the procedure for the experiment.

c. Draw the necessary tables for the experiment.

The teacher supervises them, renders help where necessary

STEP 2B: Performing Experiment or Practical

The student:

a. Set up the apparatus as in the diagram.

b. Carry out the experiment.

c. Make measurements.

The teacher supervises them, renders help where necessary

STEP 3A: Making Observations.

The students:

a. Write down the observations made from the experiment

The teacher supervises them, renders help where necessary

STEP 3B: Recording Data.

The students:

a. Write down measurements and observations in form of tables.

b. Put the correct units

The teacher supervises them, renders help where necessary

STEP 4A: Analysing result.

The students:

a. Use the formula given in the theory or derived to analyse the result.

b. Plot the graph

The teacher supervises them, renders help where necessary

STEP 4B: Interpreting and drawing conclusion.

The students:

a. interpret the result obtained in 4A

b. Draw conclusion.

If the required result is not obtained

c. Recall theory

d. With the assistance of the teacher they can change the technique

e. Perform the experiment again.

If the required result is suspected to have been obtained, the students proceed to step 5A

STEP 5A: Evaluation of method and result

a. Evaluation of the methods.

b. Evaluation of the results.

The teacher supervises them, renders help where necessary

STEP 5B: Consolidating Knowledge Gains.

a. Check if conclusion is in line with the aim of the experiment.

b. Check if the results are the required ones or not

With the assistance of the teacher

If the conclusion is in line with the aim of the experiment and the results are the required ones the problem stated in 1A is solved. If these are not the required ones then the students proceed to step 5C.

STEP 5C: Change in Technique.

a. If the conclusion is not in line with the aim (solution to the problem) or the result is not the required one.

b. Change the design or technique, with the assistance of the teacher.

The teacher allows them to ask questions at the end of each step.

Students answer the questions at the end of each topic.

Control Group.

This group followed the conventional method of teaching. Administration of pretest, posttest of Chemistry Achievement Test (CAT) and Student Attitude to practical chemistry scale were be done by the research assistants.

The teacher used the instructional guide to teach the students. (See Appendix IIIA, IIIB, IIIC).

3.9 Data Collection

The chemistry teachers of the selected schools were the research assistants who assisted in the administration and supervision of the pretest and posttest of Chemistry Achievement Test (CAT) and Students' Attitude to Practical Chemistry Scale (SAPCS) and collection of these instruments from the students before and after the administration of the treatments. Observation of the students (before and after) using the Chemistry Process Skills Rating Scale (CPSRS) was done by the research assistant in each school used for the research. The researcher went round and ensured proper administration of the instruments.

3.10 Data Analysis

The statistical tool used to establish both the main effect and interaction effect of the independent variables on the dependent variables for this study is Analysis of Covariance (ANCOVA). Scheffe pairwise post hoc analysis was used to determine the direction and magnitude of the mean difference between the groups and the level of significance.

3.11 Methodological Challenges

Despite the fact that availability of apparatus was one of the criteria for selection of the schools used for the research, the researcher still took some apparatus to some of these schools. In most of the schools the number of periods for chemistry has been reduced to three periods because of the increase in the number of subjects offered by the students, this is not adequate especially the single period is too short for the teachers and the students to perform experiments or practical. No laboratory attendants in the schools used for the research.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter presents the results of data analysis and the discussion of the findings. The data collected were subjected to Analysis of Covariance (ANCOVA). The level of significance, for the interpretation of the results was set at $p < 0.05$. The results are hereby presented in line with the order in which the hypotheses were stated in Chapter One.

4.1 Testing the Hypotheses

4.1.1 Ho_{1a}: There is no significant main effect of treatments on students' attitude to practical chemistry.

In order to test the significance of the main effect of treatments (Exp I, Exp II and Control) on students' attitude to practical chemistry, a 3 x 2 x 2 ANCOVA test was run. Table 4.1 shows the Composite table for the ANCOVA Tests.

From Table 4.1 it is clear that treatments had no significant effect on students' attitude to practical chemistry. $F_{(2, 346)} = 2.97$, $p > 0.05$, partial $\eta^2 = 0.017$. The effect size (1.7%) of treatment on attitude was low. Based on this result, the null hypothesis (Ho1a) was not rejected, that is the students' attitude is not affected by the treatment.

Discussion

The result of this study shows that treatments had no significant effect on students' attitude to practical chemistry. In support of this result is the view of Machina and Gokhley (2009) that "maintaining the levels of positive attitude towards science in early years is easier than transforming the negative attitude to positive attitude in the following years". This implies that the students' attitude to practical chemistry is already formed in the higher class (S. S. Two) used for this study. Festus and Ekpete (2012) wrote that recent reports on students' performance in chemistry show that the students still possess low attitudes towards problem-solving in chemistry.

The result of the present study is contrary to the findings of other researchers such as Gok and Silay (2010), who worked on the effects of directive and non directive problem-solving on attitude and achievement of students in a developmental science course; the result is that attitude becomes more positive after instruction. Popoola (2002) and Udosoro (2000) reported that students tend to show more positive attitudes after being exposed to self learning strategy such as computer and text assisted programmed instruction, self learning device and self instructed problem based.

Table 4.1: Test of between sample ANCOVA for the effect of treatments on students' attitude to practical chemistry

Source	Type III Sum Of squares	Df	Mean square	F	Sig	Eta squared
Corrected Model	1826.353	12	152.196	1.984	.025*	.064
Intercept	27681.75	1	27681.725	360.929	.000*	.511
PREATTIT	1.852	1	1.852	.024	.877	.000
TREAT	455.099	2	227.549	2.967	.053	.017
SIZE	164.203	1	164.203	2.141	.144	.006
SKILL	231.703	1	231.703	3.021	.083	.009
TREAT*SKILL	507.099	2	253.549	3.306	.038*	.019
TREAT * SIZE	28.026	2	14.013	.183	.833	.001
SIZE * SKILL	69.153	1	69.153	.902	.343	.003
TREAT * SIZE* SKILL	118.353	2	59.176	.772	.463	.004
Error	26536.745	346	76.696			
Total	3004519.000	359				
Corrected Total	28363.097	358				

R Squared = .064 (Adjusted R Squared = .032)

Hunt, Haidet, Coverdale, and Richards (2003) noted favourable student's attitude towards active learning methods. Also several studies such as Gonen and Basaran (2008); Ajzen and Fishbein (2000) and Wilson, Ackerman and Malave (2000), reported that students' positive attitude towards science probably correlate highly with their achievement in science. Normah and Salleh (2006) indicated that students' attitude and interests could play a substantial role among pupils studying science.

Although there was no significant effect of treatment on attitude, there is the need to examine the pre, post and the mean of students' attitude scores. Table 4.2 presents the means of each of the treatment groups' scores on attitude.

Table 4.2: Estimated marginal means for Post student' attitude to practical chemistry score.

			95% Confidence Interval for Difference	
Treatment	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
EXP 1	91.396	.796	89.832	92.961
EXP 2	93.023	1.007	91.042	95.004
CONTROL	89.810	.860	88.119	91.502

Evaluated at covariates appeared in the model: PRE ATTITUDE SCORE = 86.7549.

Table 4.2 shows that students in the Experiment 2 had highest mean score (93.02) in the students' attitude to practical chemistry while students in the control group had lowest mean score (89.81). This shows that Experiment 2 involved the students more in problem-solving activities than the other groups. This buttressed what Sule (2000) said that there is the need to advance a variety of teaching methods, having to do with heuristic problem-solving in order to promote positive attitude of students.

4.1.1 Ho_{1b}: There is no significant main effect of treatments on students' achievement in practical chemistry

A 3 x 2 x2 ANCOVA test was run in order to test the significance of the main effect of treatments (Exp I, Exp II and Control) on students' achievement in chemistry. Table 4.4 shows the Composite table for the ANCOVA Tests.

From Table 4.4 it is clear that treatments had significant effect on achievement in chemistry, $F_{(2, 346)} = 13.03$, $p < 0.05$, partial $\eta^2 = 0.070$. The effect size (7.0%) of treatment on the chemistry achievement test was high. Based on this result the null hypothesis was rejected.

Discussion

According to the result of this study, the treatments had no significant effect on the attitude of the students to practical chemistry but had significant effect on achievement in practical chemistry. This shows that attitude of the students had no effect on their achievement. This may imply that attitude had no effect on achievement. This is in agreement with Babatunde (2001)'s finding that the achievement of secondary school students in solving word problems in mathematics and physical sciences could be enhanced through problem-solving.

Having established that there was significant effect of treatments on achievement in chemistry, there is the need to examine which treatment produced the highest mean score in achievement.

Table 4.3 presents the mean score of each of the treatment groups' in chemistry test items. It shows that students in the Experiment 2 had highest mean score (20.02) in chemistry achievement test, while students in the control group had lowest mean score (15.09).

Discussion

This result shows that Experiment 2 students had more knowledge in both theoretical and practical aspects than the other groups, since both aspects were teacher and students directed. The result is in support of Senocak, Taskesenligil, and Sozbilir, (2007)'s findings that, there is a statistically significant difference between the problem-based learning and conventional groups in terms of their achievement, attitude towards chemistry, skill development and conceptual understanding.

Table 4.3: Estimated marginal means for Posttest Achievement in Chemistry Score

			95% Confidence Interval for Difference	
Treatment	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
EXP 1	18.604	.620	17.384	19.824
EXP 2	20.019	.929	18.191	21.847
CONTROL	15.091	.775	13.566	16.615

Evaluated at covariates appeared in the model PRE CHEMISTRY SCORE = 19.7103.

Table 4.4: Test of between sample ANCOVA for main effect of Treatment Groups on Posttest Achievement in Chemistry Scores

Source	Type III Sum Of squares	Df	Mean square	F	Sig	Eta squared
Corrected Model	4106.161	12	342.180	7.371	.000*	.204
Intercept	2077.478	1	2077.478	44.751	.000*	.115
PRECHEM	529.842	1	529.842	11.413	.001*	.032
TREAT	1209.540	2	604.770	13.027	.000*	.070
SKILL	471.243	1	471.243	10.151	.002*	.029
SIZE	674.845	1	674.845	14.537	.000*	.040
TREAT*SKILL	474.463	2	237.231	5.110	.006*	.029
TREAT * SIZE	97.544	2	48.772	1.051	.351	.006
SIZE * SKILL	1000.136	1	100.136	2.157	.143	.006
TREAT * SIZE* SKIL	32.694	2	16.347	.352	.703	.002
Error	16062.323	346	46.423			
Total	121318.000	359				
Corrected Total	20168.485	358				

R Squared = .204 (Adjusted R Squared = .176)

Table 4.5 shows the Scheffe Pairwise Post Hoc Analysis on Treatment Groups and Control in Achievement in Chemistry Score from this table Experiment 2 students had a mean difference of 1.42 greater than students in experiment 1 and 4.93 greater than students in the control group. The experiment 1 students had a mean difference of 3.51 greater than the control group students in achievement in chemistry scores.

Table 4.5: Pairwise Comparisons Post Hoc Test on Treatment Groups and Control in Achievement in Chemistry Score.

					95% Confidence Interval for Difference	
(I)Treatment	**(J)Treatment**	**Mean Difference**	**Std. Error**	**Sig.**	**Lower Bound**	**Upper Bound**
EXP 1	EXP 2	-1.415	1.099	.486	-4.053	1.222
	CONTROL	3.513	.977	.001	1.170	5.857
EXP 2	EXP 1	1.415	1.099	.486	-1.222	4.053
	CONTROL	4.929	1.034	000	2.447	7.411
CONTROL	EXP 1	-3.513	.977	.001	-5.857	-1.170
	EXP 2	-4.929	1.034	.000	-7.411	-2.447

Mean difference is significant at p< .05

Table 4.6: Pairwise Comparisons Post Hoc Test on Treatment Groups and Control in Achievement in chemistry Score Level of Significance

	E_1	E_2	C
E_1			*
E_2			*
C	*	*	

*= Significant difference

There are significant differences between Experiment 1 and 2 students and the control group students as shown in Table 4.6, but there is no significant difference between the students' achievement scores of the two experimental groups.

4.1.2 Ho_{2a}: There is no significant main effect of level of possession of chemistry process skills on students' attitude to practical chemistry

The significance of the main effect of level of possession of skill (High and Low) on students' attitude was tested, a 3 x 2 x 2 ANCOVA test was run. Table 4.1 shows the Composite table for the ANCOVA Tests.

From Table 4.1 it is clear that possession of chemistry process skills had no significant effect on students' attitude. $F_{(1, 346)} = 3.02$, $p > 0.05$, partial $\eta^2 = 0.009$. The effect size (0.9 %) of skill on attitude was very low. This shows that the null hypothesis was not rejected.

Discussion

The result of this study shows that chemistry process skills did not affect the students' attitude to practical chemistry, so skilled and unskilled students displayed similar attitudes. Therefore the investigation of students' attitude, behaviours, problem-solving knowledge and skills become important while solving a problem (Erdemir, 2009).

Although there was no significant effect of skill on attitude, there is the need to examine the mean students' attitude scores. Table 4.7 presents the mean of each of the groups' scores in students' attitude. It shows that students having low skill had higher mean score of 92.31.

Table 4.7: Estimated marginal means for Chemistry Process Skills on Post Students' Attitude to Practical Chemistry Score.

			95%Confidence Interval for Difference	
SKILL	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
HIGH	90.508	.817	88.901	92.116
LOW	92.311	.633	91.066	93.556

Evaluated at covariates appeared in the model: PRE ATTITUDE SCORE = 86.7549

Table 4.8: t- test for Chemistry Process Skills against Post Students' Attitude to Practical Chemistry Score

	SKILL	**N**	**Mean**	**Std Deviation**	**Std Error Mean**
POST ATTITUDE SCORE	HIGH	136	90.1250	8.7003	.7460
	LOW	223	91.6143	8.9937	.6023

Table 4.8 also shows that students with low skill had higher mean of 91.61 and students with high skill had mean of 90.13. This also shows the effectiveness of problem-solving strategy.

4.1.2 Ho_{2b}: There is no significant main effect of level of possession of chemistry process skills on students' achievement in practical chemistry

A 3 x 2 x 2 factorial ANCOVA test was run in order to test the significance of the main effect of chemistry process skills (High and low) on students' achievement in practical chemistry. Table 4.4 shows the Composite table for the ANCOVA Tests.

From Table 4.4 it is clear that chemistry process skills had significant effect on achievement in practical chemistry, $F_{(1,\ 346)} = 10.15$, $p < 0.05$, partial $\eta^2 = 0.029$. The effect (2.9%) of skill on chemistry achievement test was moderate. This shows that the null hypothesis was rejected and the alternative hypothesis accepted.

Discussion

This result shows that chemistry process skills had significant effect on achievement in practical chemistry despite the fact that there was no significant effect on attitude to practical chemistry. This also shows that attitude has no effect on achievement. This result is in agreement with Akale and Usman (1993)s' observation that the mental processes and skills associated with science can only be acquired and developed when students actually participate in science instruction through practical experience, especially as practical work has been shown to improve student's attitude towards science knowledge which could influence positive achievement in science.

Having established that there was significant effect of possession of skill on achievement in chemistry, there is the need to examine which group produced the higher mean score in achievement. Table 4.9 presents the mean score of each of the groups' in chemistry test items.

Table 4.9: Estimated marginal means for Chemistry Process Skills for Post Achievement in Chemistry Score

			95%Confidence Interval for Difference	
SKILL	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
HIGH	21.374	1.467	18.488	24.260
LOW	14.435	.856	12.751	16.119

Evaluated at covariates appeared in the model PRE CHEMISTRY SCORE = 19.7103.

Discussion

The result from table 4.9 shows that students with high chemistry process skill had higher mean score (21.37) in chemistry achievement than students with low chemistry process skill, mean score (14.44) in spite of their slightly higher attitude score. This shows that students with high chemistry process skills performed better than those with low skill, which further shows that attitude had no effect on achievement. This is also shown in tables 4.10a and 4.11 where the students with high skills had higher mean difference of 6.94 and mean 17.26 respectively. While Table 4.10b shows that both are significant.

Table 4.10a: Pairwise Comparisons Post Hoc Test on Chemistry Process Skills in post Achievement in Chemistry Score.

					95%Confidence Interval for Difference	
(I)SKILL	**(J)SKILL**	**Mean Difference**	**Std. Error**	**Sig**	**Lower Bound**	**Upper Bound**
HIGH	LOW	6.939	2.178	.002	2.655	11.222
LOW	HIGH	-6.939	2.178	.002	-11.222	-2.655

Mean difference is significant at p< .05

Table 4.10b: Pairwise Comparisons Post Hoc Test on Chemistry Process Skills in post Achievement in Chemistry Score Level of Significance

	H	L
H		*
L	*	

*= Significant difference

Table 4.11: t- test for Chemistry Process Skills against Post Achievement in Chemistry Score

	SKILL	N	Mean	Std Deviation	Std Error Mean
POST ATTITUDE	HIGH	136	17.2574	7.4337	.6374
SCORE	LOW	223	16.4978	7.5515	.5057

4.1.3 Ho3a: There is no significant main effect of class size on students' attitude to practical chemistry

In order to test the significance of the main effect of class size (Large and Small) on students' attitude a 3 x 2 x 2 ANCOVA test was run. Table 4.1 shows the composite table for the ANCOVA Tests.

From Table 4.1 it is clear that class size had no significant effect on students' attitude, $F_{(1, 346)} = 2.14$, $p > 0.05$, partial $\eta^2 = 0.006$. The effect size (0.6 %) of class size on attitude was very low. Based on this result the null hypothesis was not rejected.

Discussion

The result shows that class size whether large or small had no significant effect on students' attitude to practical chemistry. In support of the result of this study, Blatchford et al (2003) also found no statistically significant differences between class sizes for most teachers' activities.

Machina and Gokhley (2009) were of the view that "maintaining the levels of positive attitude towards science in early years is easier than transforming the negative attitude to positive attitude in the following years". This may be the reason why the treatments, level of possession of chemistry process skills and class size had no significant effect on students' attitude to practical chemistry.

Although there was no significant effect of class size on students' attitude, there is the need to examine the mean students' attitude scores. Table 4.12 presents the mean score of each of the groups' in students' attitude to practical chemistry.

Table 4.12: Estimated marginal means for Class Size for Post Students' Attitude to Practical Chemistry Score

			95%Confidence Interval for Difference	
SIZE	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
LARGE	92.170	.803	90.591	93.749
SMALL	90.650	.653	89.366	91.933

Evaluated at covariates appeared in the model: PRE ATTITUDE SCORE = 86.7549

Table 4.12 shows that the mean score is higher for the students' in large class size (92.17) than those in small class size (90.65).

Discussion

The result shows that students in large class size had greater mean score than the students in small class size this implies that problem-solving may be used for teaching large class size. In support of this result is the finding of Fleming, Toutant and Raptis (2002) who indicated that an increase in class size does not necessarily lead to a decrease in level of academic achievement. Likewise, a decrease in class size does not guarantee an improvement in the social environment of learning. They explained that the more important is what the teacher does with the opportunities provided by the size of the class. However in contrast to this result is Blatchford et al., (2003)'s account of a survey of teachers' and head teachers' views which showed that practitioners believe that large class size affect teaching and learning and are particularly aware that larger classes could have an adverse effect on amount of teachers' attention. They found that smaller classes resulted in greater teacher knowledge of pupils, frequency of one to one contacts between teachers and pupils, variety of activities, adaptation of teaching to individual pupils and opportunities to talk to parents. Other studies reported more individual teaching attention and more feedback, while monitoring, checking understanding and offering appropriate feedback to individual children is more difficult in a large class, also learning of basic skills suffer in large classes. Teachers of large classes are under stress and worn out spending many hours outside their contact time marking. That the teacher child interactions are also concerned with management activities and quelling rising noise levels. The behaviour of the pupils could be strained. This is probably related to the limited amount of space that the pupils had to move in. That grouping pupils by ability are inevitably large and included a wide range of ability. The result of this study showed that the teachers made use of the problem-solving activities which eventually led to an increase in mean gain of the large class size. There is no significant difference between the two class sizes.

4.1.3 Ho$_{3b}$: There is no significant main effect of class size on students' achievement in practical chemistry

Testing the significance of the main effect of class size (Large and Small) on students' achievement in chemistry a 3 x 2 x 2 factorial ANCOVA test was run. Table 4.4 shows the Composite table for the ANCOVA Tests.

From Table 4.4 it is clear that class size had significant effect on students' achievement in chemistry, $F_{(1,346)} = 14.54$, $p < 0.05$, partial $\eta^2 = 0.04$. The effect size (4.0%) of class size on achievement in chemistry test was moderate. This result shows that the null hypothesis was rejected and the alternative hypothesis upheld.

Discussion

This result shows that class size had significant effect on students' achievement in practical chemistry. It agrees with the reports of a study conducted in the United States by Averest and Mclennan (2011) which indicated a positive and significant effect of class size on children's test scores. They also reported a positive relationship between class size and test scores for Israel, but in contrast to this result they reported a negative but statistically insignificant effect of class size on test scores for Britain. Hanushek (2003) reported that class size is not significant in explaining students' performance. Averest and Mclennan (2011) further reported that time series evidence suggested that class size reductions in the United states over the last three decades have not led to improvements in students' performance. In Nigeria Babatunde and Olanrewaju (2014) reported that class size has effect on students' achievement. On the contrary Adeyemi (2008) discovered that there is no significant relationship among class size and students' learning outcomes.

Having established that there was significant effect of class size on achievement in chemistry, there is the need to examine which group produced the higher mean score in achievement. Table 4.13 presents the mean of each of the groups' scores in chemistry test items.

Table 4.13: Estimated marginal means for Class Size for Post Achievement in Chemistry Score

			95%Confidence Interval for Difference	
SIZE	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
LARGE	16.377	.701	14.998	17.756
SMALL	19.432	.586	18.279	20.585

Evaluated at covariates appeared in the model PRE CHEMISTRY SCORE = 19.7103.

Table 4.14a: Pairwise Comparisons Post Hoc Test on Class Size in post Achievement in Chemistry Score.

					95%Confidence Interval for Difference	
(I)SIZE	**(J)SIZE**	**Mean Difference**	**Std. Error**	**Sig**	**Lower Bound**	**Upper Bound**
LARGE	SMALL	-3.055	.801	.000	-4.631	-1.479
SMALL	LARGE	3.055	.801	.000	1.479	4.631

Mean difference is significant at p< .05

Table 4.14b: Pairwise Comparisons Post Hoc Test on Class Size in post Achievement in Chemistry Score Level of Significance

	L	S
L		*
S	*	

*= Significance difference

Table 4.13, 4.14a and 4.14b show that students in small class size had higher mean score (19.43) in chemistry achievement than students in large class size of mean score (16.38). Also these students in small class size had higher mean difference of 3.05. Both are significant.

Discussion

The results of this study show that students in small class size gained more academically than the students in the large class size with a greater mean difference of 3.06 in the achievement test. While the difference in mean between the large class size and small class size was only 1.52 in the students' attitude to practical chemistry score. This may be considered as one of the advantages of small class size over the large class size. This result is in agreement with Blatchford et al., (2003)'s report, who pointed out that small classes can encourage aspects of teaching that are the same as those identified in research on effective teaching (e.g immediate feedback, sustaining purposeful interactions) linked with the promotion of pupils achievement. Also in support of this is Kokkelenberg et al., (2005)'s argument that courses geared towards promoting critical thinking and advanced problem-solving are best taught in a smaller classroom environment. Averest and Mclennan (2011) concluded that Senior Secondary Students in small sized classes show higher achievement in chemistry relative to their colleagues in large sized classes. Ogundipe (2004) showed that reduced class size with a 1:15 teacher- student ratio showed positive results on reading and mathematics. Also Adeyemi (2008) found that schools having an average class size ≤ 35 obtained better results than those having > 35.

In contrast to the result of this study, are the results of some studies which show no significant relationship between class size and students' performance (Carpenter, 2006). While other studies in support of this study favour small class environments, results vary based on the criteria used to gauge student performance as well as the class size measure itself. When traditional achievement tests are used, small classes may provide no advantage over large classes. However if additional performance criteria are used (e.g. long term retention, problem-solving skills), it appears that small classes hold an advantage (Aria and Walker, 2004).

4.1.4 Ho_{4a}: There is no significant interaction effect of treatments and level of possession of chemistry process skills on students' attitude to practical chemistry score

In order to test the significance of the interaction effect of treatments and level of possession of chemistry process skills on students' attitude a 3 x 2 x 2 factorial ANCOVA test was run. Table 4.1 shows the Composite table for the ANCOVA Tests.

From Table 4.1 it is clear that interaction of treatments and chemistry process skills had significant effect on students' attitude, $F_{(2, 346)} = 3.31$, $p < 0.05$, partial $\eta^2 = 0.019$. The effect size of the interaction was fair (1.9%). This shows that the null hypothesis is rejected and the alternative hypothesis upheld.

Discussion

This result shows that the interaction between treatments and chemistry process skills had significant effect on students' attitude to practical chemistry. Research has demonstrated that attitude toward science changes with exposure to science but that the direction of change may be related to the quality of that exposure, the learning environment and teaching method (Cracker, 2006). This shows that the exposure and the teaching method are of high quality to have a positive effect on students' attitude to practical chemistry. Cardelini (2006) discovered that students' attitude towards science is more likely to influence the success in science courses than success influencing attitude.

Table 4.15 shows the mean, standard error and 95% confidence interval of the mean scores. The table shows that students in Experiment 2 with low skill had the highest mean score (93.99) in students' attitude.

Table 4.15: Estimated marginal means for Treatments and Chemistry Process Skills for Post Students' Attitude to Practical Chemistry Score

				95% Confidence Interval for Difference	
Treatment	**Skill**	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
EXP 1	HIGH	89.026	1.057	86.947	91.105
	LOW	93.767	1.193	91.421	96.112
EXP 2	HIGH	92.053	1.661	88.786	95.319
	LOW	93.994	1.146	91.740	96.247
CONTROL	HIGH	90.447	1.446	87.603	93.290
	LOW	89.174	.930	87.345	91.003

Evaluated at covariates appeared in the model: PRE ATTITUDE SCORE = 86.75

This result is in agreement with the findings of Senoocak, Taskesenligil and Sozbilir (2007) that there was a statistically significant difference between the problem-based learning and conventional groups in terms of their attitude towards chemistry, skills development and conceptual understanding. It is at variance with Frazer and Sleet cited in Sule (2000), findings that seventy six percent of the unsuccessful students in a study they conducted had negative attitude towards problem-solving.

To disentangle the interaction a graph is plotted. This is shown in Figure 4.1

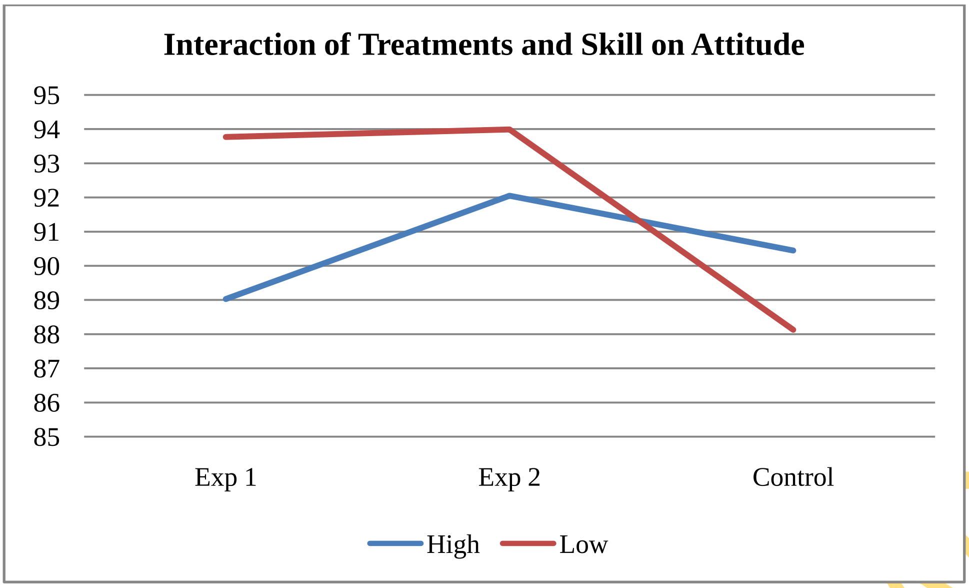

Figure 4.1: Interaction of Treatments and Chemistry Process Skills on Students' Attitude to Practical Chemistry Score

This result of the study shows the efficacy of the problem-solving strategy which has led to the development of high attitude in the students with low chemistry process skills. This was reversed in the control which is the conventional group. There is interaction between the treatment and chemistry process skills on students' attitude to chemistry score.

4.1.4 Ho$_{4b}$: There is no significant interaction effect of treatments and chemistry process skills on students' achievement in practical chemistry

A 3 x 2 x 2 factorial ANCOVA test was run in order to test the significance of the interaction effect of treatment and skill on students' achievement in chemistry. Table 4.4 shows the Composite table for the ANCOVA Tests.

From Table 4.4 it is clear that interaction of treatments and chemistry process skills had significant effect on chemistry achievement, $F_{(2,346)} = 5.11$, $p < 0.05$, partial $\eta^2 = 0.029$. The effect size of the interaction was moderate (2.9%). This result showed that the null hypothesis was not accepted.

Discussion

The result of this study shows that the interaction of treatments and chemistry process skills had significant effect on students' achievement in practical chemistry. This finding is similar to that of several studies, such as Gonen and Basaran (2008), Ajzen and Fishbein (2000); Wilson, Ackerman and Malave (2000) who reported that students' positive attitude towards science correlate highly with their achievement in science. The results of this study show that the interaction of treatments and chemistry process skills is very strong because it had effect on both students' attitude and achievement in practical chemistry. These results also show that acquisition of chemistry process skills is important.

Table 4.16 shows the descriptive statistics the mean, standard error and 95% confidence interval of the mean scores. The table shows that students in Experiment 2 and with High skill had the highest mean score (28.58) in chemistry achievement test.

Table 4.16: Estimated marginal means for Treatments and Chemistry Process Skills for Post Achievement in Chemistry Score

				95% Confidence Interval for Difference	
Treatment	**Skill**	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
EXP 1	HIGH	25.396	1.109	23.215	27.557
	LOW	21.812	1.141	19.569	24.055
EXP 2	HIGH	28.581	2.106	24.439	32.723
	LOW	21.457	1.111	19.273	23.642
CONTROL	HIGH	25.144	1.923	21.362	28.927
	LOW	15.037	1.059	12.954	17.119

Evaluated at covariates appeared in the model PRE CHEMISTRY SCORE = 19.7103

To disentangle the interaction a graph is plotted. This is shown in Figure 4.2

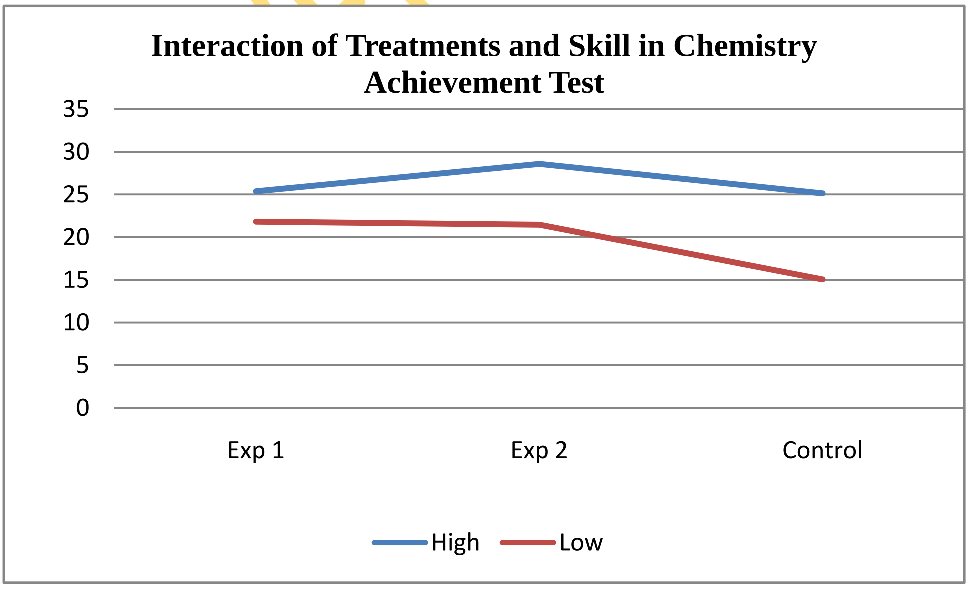

Figure 4.2: Interaction of Treatments and Skill on Chemistry Achievement Test

Discussion

The possession of high skill and high scores in the chemistry achievement test which is the result of this study is supported by Gok and Silay (2010) that problem-solving is one of the most important issues in teaching and learning. The role of problem-solving in science is indispensable. It is an integral part of science. Science itself is a problem-solving subject. It is a subject that revolves around finding one solution or the other to some problems. Problem-solving can and should be the centre of the instruction, also the way it is practiced must change, it should be a part of an active learning of the instructional process. When students know all the relevant facts and principles necessary for the solution of a problem, they may be unable to solve it because they lack any systematic strategy for guiding them to apply such facts and principles. The result showed that Experiment 2 involved the students most in the problem-solving activities.

4.1.5 Ho_{5a}: There is no significant interaction effect of treatments and class size on students' attitude to practical chemistry

In order to test the significance of the interaction effect of treatments and class size on students' attitude a 3 x 2 x 2 factorial ANCOVA test was run. Table 4.1 shows the Composite table for the ANCOVA Tests.

From Table 4.1 it is clear that interaction of treatments and class size had no significant effect on students' attitude, $F_{(2,\ 346)} = 0.83$, $p > 0.05$, partial $\eta^2 = 0.009$. The effect size of the interaction was small (0.9%). This means that the null hypothesis was not rejected.

Discussion

This result shows that the interaction between the treatments and large or small class size class size had no significant effect on students' attitude to practical chemistry. This shows that the interaction effect is very low.

Table 4.17 shows the descriptive statistics, the mean, standard error and 95% confidence interval of the mean scores. The table shows that students in Experiment 2 and in large class size had the highest mean score in students' attitude to practical chemistry.

Discussion

This result shows that Experiment 2 exposed students to more problem-solving activities and the teachers made the most use of the activities which led to the increase in attitude of the students in the large class size.

Table 4.17: Estimated marginal means for Treatments and Class Size for Post Students' Attitude to Practical Chemistry Score

				95% Confidence Interval for Difference	
Treatment	**Class Size**	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
EXP 1	LARGE	91.925	1.231	89.503	94.347
	SMALL	90.868	1.030	88.841	92.894
EXP 2	LARGE	93.591	1.644	90.358	96.824
	SMALL	92.455	1.165	90.163	94.747
CONTROL	LARGE	90.994	1.241	88.553	93.436
	SMALL	88.626	1.190	86.285	90.967

Evaluated at covariates appeared in the model: PRE ATTITUDE SCORE = 86.7549

4.1.5 Ho_{5b}: There is no significant interaction effect of treatments and class size on students' achievement in practical chemistry

Testing the significance of the interaction effect of treatment and class size on students' achievement in chemistry a 3 x 2 x 2 factorial ANCOVA test was run. Table 4.4 shows the Composite table for the ANCOVA Tests.

From Table 4.4 it is clear that the interaction of treatments and class size had no significant effect on chemistry achievement, $F_{(2, 346)} = 1.05$, $p > 0.05$, partial $\eta^2 = 0.006$. The effect size of the interaction was small (0.6%). The result showed that the null hypothesis is upheld.

Discussion

The interaction of treatments and class size had no significant effect on achievement in practical chemistry. This shows that the effect of the interaction between treatments and class size was so small that it had no effect on achievement in practical chemistry. In support of this result is Afolabi (2002), who found no significant relationship among class size and students' learning outcome in the treatment groups.

Table 4.18 shows the descriptive statistics the mean, standard error and 95% confidence interval of the mean scores. The table shows that students in Experiment 2 in small class size had the highest mean score in chemistry achievement test.

Table 4.18: Estimated marginal means for Treatments and Class Size for Post Achievement in Chemistry Score

				95% Confidence Interval for Difference	
Treatment	**Class Size**	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
EXP 1	LARGE	16.515	.952	14.643	18.388
	SMALL	20.692	.793	19.133	22.252
EXP 2	LARGE	19.342	1.385	16.617	22.067
	SMALL	20.697	1.019	18.692	22.701
CONTROL	LARGE	13.274	1.040	11.228	15.321
	SMALL	16.907	1.004	14.932	18.881

Evaluated at covariates appeared in the model PRE CHEMISTRY SCORE = 19.7103

Discussion

The result of this study on the effect of the interaction of treatments and class size shows that students in small class sizes in Experiments 1 and 2 had the high mean scores in the achievement test. This is supported by Mokobia and Okoye (2011)'s and Falls (2003)'s observations that, according to many parents, educators and policy makers, smaller classes are an apparently full proof prescription for improving students' performance. That is fewer students means more individual attention from the teachers, calmer classrooms and consequently, higher test scores.

4.1.6 Ho_{6a}: There is no statistically significant interaction effect of chemistry process skills and class size on students' attitude to practical chemistry

The significance of the interaction effect of chemistry process skills and class size on students' attitude was tested a 3 x 2 x 2 factorial ANCOVA test was run. Table 4.1 shows the Composite table for the ANCOVA Tests.

From Table 4.1 it is clear that the interaction of chemistry process skills and class size had no significant effect on students' attitude, $F_{(1, 346)} = 0.90$, $p > 0.05$, partial $\eta^2 = 0.003$. The effect size of the interaction was low (0.3%). The result shows that the null hypothesis is not rejected.

Discussion

The result of this study shows that the interaction effect of chemistry process skills and class size was low and had no significant effect on students' attitude. Table 4.1 also shows that both chemistry process skills and class size had no significant effect on students' attitude when considered separately.

Table 4.19 shows the descriptive statistics the mean, standard error and 95% confidence interval of the mean scores. The table shows that students in large classes with low chemistry process skill had the highest mean score in students' attitude to practical chemistry.

Table 4.19: Estimated marginal means for Chemistry Process Skills and Class Size for Post Students' Attitude to Practical Chemistry Score

				95%Confidence Interval for Difference	
SKILL	**SIZE**	**Mean**	**Std Error**	**Lower Bound**	**Upper Bound**
HIGH	LARGE	90.780	1.239	88.343	93.217
	SMALL	90.237	1.065	88.142	92.331
LOW	LARGE	93.560	1.017	91.559	95.561
	SMALL	91.062	.756	89.575	92.550

Evaluated at covariates appeared in the model: PRE ATTITUDE SCORE = 86.7549

Discussion

Although the result of this study shows that the interaction effect of chemistry process skills and class size had no significant effect on students' attitude, but students in large class size despite the size of the class and their low level of chemistry process skills still had the highest mean score in students' attitude to practical chemistry showed the effectiveness of problem-solving strategy.

4.1.6 Ho$_{6b}$: There is no significant interaction effect of chemistry process skills and class size on students' achievement in practical chemistry

In order to test the significance of the interaction effect of chemistry process skills and class size on students' achievement in chemistry a 3 x 2 x 2 factorial ANCOVA test was run. Table 4.4 shows the Composite table for the ANCOVA Tests.

From Table 4.4 it is clear that the interaction of chemistry process skills and class size had no significant effect on achievement in chemistry, $F_{(1, 346)} = 2.16$, $p > 0.05$, partial $\eta^2 = 0.006$. The effect size of the interaction was low (0.6%). The null hypothesis is not rejected.

Discussion

From the result of this study the effect of the interaction of chemistry process skills and class size was also low that it had no significant effect on achievement in practical chemistry, where as the effect of chemistry process skills and class size separately had significant effect on achievement in chemistry.

Table 4.20 shows the descriptive statistics the mean, standard error and 95% confidence interval of the mean scores. The table shows that students in small class size with high skill had 23.489, which is the highest mean score in achievement in chemistry test.

Table 4.20: Estimated marginal means for Chemistry Process Skills and Class Size for Achievement in Chemistry Score

				95%Confidence Interval for Difference	
SKILL	**SIZE**	**Mean**	**Std Error**	**Lower Bound**	**Upper Bound**
HIGH	LARGE	19.258	1.652	16.008	22.509
	SMALL	23.489	1.541	20.458	26.520
LOW	LARGE	13.496	1.052	11.426	15.566
	SMALL	15.375	.917	13.570	17.179

Evaluated at covariates appeared in the model: PRE CHEMISTRY SCORE = 19.7103

Discussion

The result of this study shows that the students in small class size with high skill had the highest mean score in achievement in chemistry, where as they had the lowest score in attitude to chemistry scores. In support of this finding is the report of Aria and Walker, (2004) on studies in favour of small class environments. That the results vary based on the criteria used to gauge students' performance as well as the class size measure, when traditional achievement tests are used, small classes may provide no advantage over large classes. However if additional performance criteria are used (e.g. long term retention, problem-solving skills), it appears that small classes hold an advantage.

4.1.7 Ho_{7a}: There is no statistically significant interaction effect of treatments, chemistry process skills and class size on students' attitude to practical chemistry.

The significance of the interaction effect of treatments, chemistry process skills and class size on students' attitude was tested a 3 x 2 x 2 factorial ANCOVA test was run. Table 4.1 shows the Composite table for the ANCOVA Tests.

From Table 4.1 it is clear that interaction of treatments, chemistry process skills and class size had no significant effect on students' attitude, $F_{(2, 346)} = 0.77$, $p > 0.05$, partial $\eta^2 = 0.004$. The effect size of the interaction was small (0.4%). The null hypothesis was not rejected.

Discussion

The interaction is not significant. Therefore the assumption of homogeneity of regression slopes is not violated. This means full ANCOVA can be conducted. It follows that the effect of treatments on students' attitude to practical chemistry is not sensitive to chemistry process skills-class size combination.

Table 4.21 shows that students in Experiment 2 with low skill in large class size had the highest mean score of 95.01. This shows the effectiveness of Experiment 2 approach.

Table 4.21: Estimated Marginal Means for Treatment, Chemistry Process Skills and Class Size for Post Students' Attitude to Practical Chemistry Score

					95% Confidence Interval for Difference	
Treatment	**Skill**	**Class Size**	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
EXP 1	HIGH	LARGE	89.480	1.542	86.947	92.512
		SMALL	88.572	1.463	85.694	91.450
	LOW	LARGE	94.370	1.912	90.608	98.131
		SMALL	93.164	1.436	90.340	95.984
EXP 2	HIGH	LARGE	91.169	2.642	85.973	96.365
		SMALL	92.936	2.010	88.982	96.890
	LOW	LARGE	95.013	1.960	92.158	99.869
		SMALL	91.974	1.183	89.648	94.300
CONTROL	HIGH	LARGE	91.692	2.074	87.613	95.770
		SMALL	89.202	2.010	85.249	93.155
	LOW	LARGE	90.297	1.354	87.635	92.960
		SMALL	88.050	1.278	85.536	90.564

Evaluated at covariates appeared in the model: PRE ATTITUDE SCORE = 86.7549

4.1.7 Ho_{7b}: There is no significant interaction effect of treatments, chemistry process skills and class size on students' achievement in practical chemistry

A 3 x 2 x 2 factorial ANCOVA test was run in order to test the significance of the interaction effect of treatments, chemistry process skills and class size on students' achievement in chemistry. Table 4.4 shows the Composite table for the ANCOVA Tests.

From Table 4.4 it is clear that interaction of treatments, chemistry process skills and class size had no significant effect on students' achievement in chemistry, $F_{(2, 346)} = 0.35$, $p > 0.05$, partial $\eta^2 = 0.002$. The effect size of the interaction was very small (0.2%). Based on this the null hypothesis was upheld.

Discussion

The result shows that the students' achievement in chemistry is not significantly affected by interaction of treatments, chemistry process skills and class size. It also shows that the effect of treatments on students' achievement in chemistry is not sensitive to chemistry process skills-class size combination. This result when viewed against the background of main effect of treatments on students' attitude to and achievement in practical chemistry tends to suggest that practicing chemistry teachers should use problem-solving strategy for teaching, irrespective of the chemistry process skills-class size combination. Although treatments significantly improved the level of students' achievement in chemistry highly, so also chemistry process skills and class size but the levels of this increase were not high. This should be expected because studying science especially chemistry using problem-solving strategy is not common in our schools.

Table 4.22: Estimated marginal means for Chemistry Process Skills and Class Size for Achievement in Chemistry Score

					95% Confidence Interval for Difference	
Treatment	**Skill**	**Class Size**	**Mean**	**Std. Error**	**Lower Bound**	**Upper Bound**
EXP 1	HIGH	LARGE	17.581	1.396	14.934	20.328
		SMALL	23.211	1.363	20.531	25.891
	LOW	LARGE	15.449	1.620	12.264	18.635
		SMALL	18.174	1.302	15.613	20.735
EXP 2	HIGH	LARGE	21.989	2.679	16.721	27.258
		SMALL	25.173	2.243	20.761	29.585
	LOW	LARGE	16.694	1.658	13.434	19.954
		SMALL	16.221	1.141	13.976	18.466
CONTROL	HIGH	LARGE	18.205	2.260	13.760	22.650
		SMALL	22.084	2.192	17.774	26.394
	LOW	LARGE	8.344	1.313	5.762	10.926
		SMALL	11.729	1.251	9.268	14.190

Evaluated at covariates appeared in the model: PRE ATTITUDE SCORE = 19.7103

From table 4.22 students in Experiment 2 with high skill and in small class size had the highest mean score in the achievement in chemistry test. This further shows the effectiveness of Experiment 2 approach.

Table 4.23: Between-Subject Factor

		Value Label	N
TREATMENT	1.00	EXP 1	128
	2.00	EXP 2	105
	3.00	CONTROL	126
SKILL	1	HIGH	136
	2	LOW	223
SIZE	1	LARGE	219
	2	SMALL	140

Table 4.23 shows the number of subjects in each of the groups.

Discussion

From this table the total number of students in the large class size is 219 whereas in Table 3.3 the total number of students in the large class size was 299. The difference in the number of students shows the disadvantage of large class size, where these students did only the pretest or posttest and not both as expected. This is the reason why the number of students in Table 3.3 (439) is greater than the number of students in the analysis (359) as in Tables 4.1 and 4.4. This is supported by Wang and Zhang (2011) who wrote that large classes are difficult to control.

CHAPTER FIVE

5.0 SUMMARY OF FINDINGS, IMPLICATIONS AND RECOMENDATIONS

This chapter presents a summary of the findings discussed in chapter four, their educational implications and proffers some recommendations. It also presents some limitations of the study and suggestions for further research.

5.1 Summary of Findings

1. The treatments had no effect on students' attitude to practical chemistry, but had effect on achievement in chemistry. This implies that students' attitude may not have effect on achievement in chemistry.
2. Chemistry process skills also did not affect the students' attitude to practical chemistry, but affected the achievement in chemistry.
3. Class size also had no effect on students' attitude to practical chemistry, but had effect on achievement in chemistry. This may be that at the Senior Secondary School level the students already formed their attitude to practical chemistry such that none of the treatments, chemistry process skills or class size had effect on it.
4. The two way interaction of treatments and chemistry process skills had effect on both students' attitude to practical chemistry and achievement in chemistry. This shows the importance of acquisition of chemistry process skills.
5. On the contrary the two way interaction of treatments and class size did not affect both students' attitude to practical chemistry and achievement in chemistry.
6. The two way interaction of class size and chemistry process skills had no effect on both the students' attitude to practical chemistry and achievement in chemistry.
7. The three way interaction of treatments, class size and chemistry process skills had no effect on both students' attitude to practical chemistry and achievement in chemistry.
8. Students exposed to Experiment 2 had the highest mean score in students' attitude to and achievement in chemistry.
9. Students with low chemistry process skills had higher mean score in students' attitude to practical chemistry, but students with high chemistry process skills had higher mean score in achievement in chemistry.
10. Students in large class size had the higher mean score in students' attitude to practical chemistry, while students in small class size had the higher mean score in achievement in chemistry.

11 Students exposed to Experiment 2 with low chemistry process skills had the highest mean score in the two way interaction between treatments and chemistry process skills in students' attitude to practical chemistry. The students in Experiment 2 group with high chemistry process skills had the highest mean score in the two way interaction between treatments and chemistry process skills in achievement in chemistry.

12 Also students in Experiment 2 group in large class size had the highest mean score in the two way interaction between treatments and class size in students' attitude to practical chemistry. Again those in this group but in small class size had the highest mean score in achievement in practical chemistry in the two way interaction.

13 Students in large class size with low chemistry process skills had the highest mean score in the two way interaction between class size and chemistry process skills in students' attitude to practical chemistry. While students in small class size with high chemistry process skills had the highest mean score in the two way interaction between class size and chemistry process skills in achievement in chemistry.

14 The three way interaction of treatments, chemistry process skills and class size had no effect on both students' attitude to and achievement in chemistry. Students in Experiment 2 group with low skill in large class size had the highest mean score in students' attitude to practical chemistry, while students in this group with high skill and in small class size had the highest mean score in achievement in chemistry.

However there was no effect of treatments, chemistry process skills and class size on students' attitude to chemistry. Also the two way interaction of treatments and class size, class size and chemistry process skills and the three way interaction of treatments, class size and chemistry process skills had no effect on students' attitude to practical chemistry. Only the two way interaction of treatments, and chemistry process skills had significant effect on the students' attitude to practical chemistry.

On the contrary the treatments, chemistry process skills and class size had significant effect on students' achievement in chemistry. Also the two way interaction of treatments and chemistry process skills had significant effect on students' achievement in chemistry too, but the two way interaction of treatments and class size, class size and chemistry process skills and the three way interaction of treatments, class size and chemistry process skills had no significant effect on students' achievement in chemistry too.

In establishing which group had the highest mean score, it was discovered that students' exposed to Experiment 2 had the highest mean score in the following:

1 Attitude to practical chemistry.

2 Achievement in chemistry.

3 The two way interaction between treatments and chemistry process skills on students' attitude to practical chemistry, students' with low chemistry process skills had the highest. While students' with high chemistry process skills had the highest mean score in achievement in chemistry.

4 The two way interaction between treatments and class size, students in the large class size had the highest mean score in students' attitude to practical chemistry. Also students in small class size had the highest mean score in achievement in chemistry. Students with low skill had higher mean gain in students' attitude to practical chemistry while students with high skill had the highest mean score in achievement in chemistry. Students in large class size had higher mean gain in students' attitude to practical chemistry, while students in small class size had the higher mean gain in achievement in chemistry. In the two way interaction between class size and chemistry process skills, students in large class size with low chemistry process skills had the higher mean score in students' attitude to practical chemistry. While students in small class size with high chemistry process skills had the highest mean score in achievement.

From the results, the treatments, chemistry process skills and class size had significant effect on the students' achievement in chemistry. Also, students exposed to Experiment 2 had the highest mean score in all the variables which shows the effectiveness of the method, while students with high skill and those in small class size had the higher mean score in achievement test.

5.2 Implications and Recommendations

The study revealed the degree of influence of problem-solving, level of acquisition of chemistry process skills and effect of class size on attitude to and achievement in practical chemistry in Oyo state. These findings have implications for education policy makers, administrators, curriculum planners or developers and practicing teachers. The result of this study has shown that problem-solving strategy in the teaching and learning of chemistry is better than the conventional (control) method. Problem-solving strategy has also been found to be more effective in improving the problem-solving attitude and academic performance of the students, not only in the small classes but in the large classes, and students with low chemistry process skills. It has also been found that the problem-solving approach in Experiment 2 is more effective than the problem-solving approach in Experiment1 in improving the attitude and academic performance of the students in the large class and those with low chemistry process skills.

Practicing Teachers: In the light of these findings, it is necessary for chemistry teachers to review their methods of teaching to be student centered but guided by the teacher especially in large classes as we have in most of our schools, using problem-solving strategy. The inability of science teachers to use problem-solving strategy may be due to lack of understanding of the problem-solving instructional approaches and the implementation, or due to conservatism, where in teachers tend to teach the way they were taught. Teacher education should help teachers to be flexible enough to easily adapt to changes, since science is dynamic.

There is need for pre- service and in- service courses, workshops and seminars that focus more on the role of practical work, especially problem-solving strategy, in creating opportunities for students to learn and do science. Students should be guided to discover scientific facts themselves. There is therefore need for teachers to motivate, encourage and help students to develop positive attitude towards chemistry, which can be achieved through the teaching methodology (problem- solving strategy)

Teachers should attend in- service training, workshops and seminars to be able to improve their methodologies and update their knowledge on the course contents. This would help the science teachers to learn more about problem-solving teaching strategy, knowledge and skills for laboratory work, which they can impact on the students.

Curriculum Planners: There is need to change science teachers' education courses, so that more problem-solving approaches could be incorporated. There is need to revise the chemistry curriculum to give room for practical oriented topics and activities that will enhance technological development of the nation. This will help to develop scientific potentials of our youths.

Policy Makers and Administrators:

There is the need to reinforce the monitoring units to ensure that teachers use the right methodology and carry out practical frequently. Effective and workable facilities should be provided if teachers are to venture into a more tasking problem-solving instructional approach. Laboratory environment should be conducive and motivating to both teachers and students. Science teachers need incentives as par fantastic science teachers' allowance to enable them cope with the demanding nature of problem-solving. Laboratory assistants should be posted to schools to make the setting of the laboratory for practical easier and faster for the teachers. Also four periods should be allotted to science subjects and these should be double periods each, so that the teachers will have enough time to perform experiments and practical during the lesson where necessary.

5.3 Limitations and Suggestions for Further Research

This study was limited to SS 2 science students in three educational zones and nine local government areas in Ibadan and Oyo towns. Further research in the other educational zones and local government areas is recommended to provide more room for generalization. The study focused on public state schools, further research could focus on private and federal government schools.

The content areas for this study are: Nature of Matter, Separating Techniques and Volumetric Analysis. The problem-solving instructional guides were developed in these content areas. There is therefore the need to develop more problem-solving instructional guides in other content areas such as Atomic Structure, Gas Laws, Metals and Non metals and Organic chemistry.

Outstanding limitations to this study are inadequate chemistry apparatus and laboratory assistants. Most schools visited had limited number of chemistry apparatus compared with the number of students offering the subject in each school, the researcher carried some apparatus to some of the schools used for the research despite the fact that these schools were selected on the basis of the availability of these apparatuses. In most of the schools the number of periods for chemistry has been reduced to three periods because of the increase in the number of subjects offered by the students, this is not adequate especially the single is too short for the teachers and the students to perform experiments or practical. No laboratory assistant in all the schools used for the research.

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APPENDIX IA

LABORATORY PROBLEM-SOLVING MODEL (LAPSOM) INSTRUCTIONAL GUIDE on Nature of Matter

The teacher teaches the students the background information first.

The teacher asks the following questions:

What is matter?

What is it made up of?

He explains that matter is anything that has weight and occupies space. It is made up of discrete particle, such as atoms and molecules. An atom is the smallest particle of an element which can take part in chemical reaction.

The teacher asks the questions;

What is a molecule?

What is a compound?

The teacher explains that a molecule is the smallest particle of a substance that can normally exist alone and still retain chemical properties of that substance either an element or compound. Elements combine to form compounds while atoms combine to form molecules.

The teacher asks the following question;

What are physical and chemical changes? The teacher explains that a physical change is one which is easily reversed and in which no new substances are formed.

Classify the following into physical and chemical changes.

Salt + water $\longrightarrow$ salt solution

Wood $\longrightarrow$ ash +gases

Stage 1- Recognize the problem.

The students are given the laboratory manual which consists of stages 1 -5. The practical problem posed is;

Nature of matter – physical and chemical changes, elements, compounds and mixtures and the determination of empirical formula of magnesium oxide.

Read carefully the laboratory manual.

Recognize the apparatus provided.

Check the soundness of the apparatus.

Read the instruction again.

Sketch a diagram of how you intend to arrange the apparatus to enable you solve the problem.

Stage2: Recall background Information.

Actions: (a) Write down known general principles and mathematical expressions are necessary for solving the problem .

(b) List possible sources of error in solving the problem.

(c) Recognize independent and dependent variables in the problem and note their relationship.

STAGE 3; Conduct the Experiment, Predicting from data.

METHOD OR PROCEDURE

Students should

Weigh the crucible with the lid.

Clean magnesium ribbon with sandpaper.

Cut 15cm of clean magnesium ribbon into the crucible.

Place the crucible on the tripod stand, heat strongly and remove the lid at intervals with the tong.

When the magnesium has burned completely, remove the lid and continue heating for two minutes.

Remove the crucible from the tripod stand and keep in a desiccator.

Weigh the crucible, content and lid when it is completely cold.

Repeat heating for three minutes. Allow the crucible, content and lid to cool then weigh again.

OBSERVATION: Students should record all observations.

Repeat the experiment again and calculate the average of the figures.

RESULT:

Mass of crucible and lid=

Mass of crucible, lid and magnesium =

Mass of crucible, lid and content after heating =

Mass of content =

Mass of magnesium =

Mass of oxygen =

QUESTIONS:

1) Name the elements involved in the experiment?
2) Name the compound formed?
3) What is the mass of crucible and lid?
4) Why do we need to clean the magnesium ribbon?
5) Why do we need to lift the lid when the magnesium was burning?
6) Why do we need to continue to heat the crucible for another 2 minutes?

7) What makes the magnesium change color?

8) What supports the burning of magnesium?

9) What is the name of the new substance?

10) How would you find out the mass of magnesium and mass of the magnesium oxide

11) If the relative atomic mass of magnesium is 24 and oxygen is 16, how many atoms of magnesium were used?

12) How many atoms of oxygen were used?

13) What is the ratio of atoms of magnesium to oxygen?

14) Derive the formula for the magnesium oxide?

15) Does the experiment involve physical or chemical change? Give reason for your answer?

16) What have you learnt from the experiment which is applicable to everyday life?

17) Is there any reason for repeating the experiment and why?

NOTE: There are no variation of variables and plotting of graphs in this study. Part of stages 3B-5A are not necessary, stage 5B is taken care of by answering the questions. The answers to the questions will determine whether to repeat the experiment or not.

APPENDIX IB

LABORATORY PROBLEM-SOLVING MODEL (LAPSOM) INSTRUCTIONAL GUIDE on Separation Techniques

The teacher teaches the students the background to the problem.

Mixtures contain two or more different substances. Each constituent of a mixture still retains its individual properties. We can take advantage of these characteristics to separate mixtures. Thus the technique employed in separating mixtures makes use of the physical properties of their constituents.

SUBLIMATION: Asks the students to state the states of matter and sublimation. The three states of matter are solid, liquid and gas, while sublimation is the direct conversion of a solid to the gaseous state directly without changing to the liquid state. Asks the students to write examples on the board. Gives example of camphor.

FILTRATION: This is used to separate an insoluble solid from a liquid. This involves the use of a filter paper which is porous in nature and allows the passage of only water which is the filtrate, while the particles remain in the funnel as residue. Industries such as water purification plant and breweries use filtration to remove solid particles from liquids. Also in the purification of pipe-borne water, the water strains through the various layers of the filter bed, leaving all forms of suspended materials behind. The filtered water is then treated with chemicals to kill any bacteria in it before being piped to the consumers.

EVAPORATION TO DRYNESS: This method can be used to recover a solid solute from a solution, the solvent escapes into the atmosphere as vapour leaving the solute in the evaporating dish.

$$\text{Solution} \xrightarrow{\hspace{2cm}} \text{solute + solvent}$$

Evaporation can be done at a steady rate using a water bath or a sand bath. This method cannot be used to recover salts that are easily destroyed by heating. This method is used in salt making industries. Sea water is pumped into trenches and allowed to evaporate under the heat of the sun along the Western Coast of Africa. All the water dries up leaving behind the salt.

SEPARATING FUNNEL METHOD: Some liquids do not mix together; these are known as immiscible liquids e.g water and oil, water and petrol. Those that mix together to form a homogenous liquid are called miscible liquids e.g water and alcohol. The immiscible liquids form two distinct layers when added together, a separating funnel can be used to separate the two layers into two different containers, the lower denser layer is collected before the less dense upper layer.

STAGE 1: Recognize the problem.

The students are given the laboratory manual which consists of stages 1-5 of the model.

a. The students should recognize that the problem posed is the aim of each experiment.
b. Read carefully the laboratory manual.
c. Identify the apparatus provided.
d. Check the soundness of the apparatus.
e. Read the instruction again.
f. Sketch the diagram of how you intend to arrange the apparatus to solve the problem.

STAGE 2: Recall background information.

(a) List the sources of error and precautions to be taken in each experiment.

STAGE 3: Conduct the Experiment.

SUBLIMATION:

- Pour the mixture to be separated for example sodium chloride (NaCl) and Iodine (I_2) in an evaporating dish.
- Cover with an inverted funnel and heat indirectly on a water bath.
- Note what happens to the iodine.
- Scrape off the iodine into a Petri dish.

PRECAUTIONS:

- Avoid gas leakage during heating.
- Be very careful when removing the funnel, so that the iodine does not mix with the sodium chloride.

QUESTIONS

1 Why do we heat indirectly on a water bath?.

2 Why do we cover with inverted funnel?

3 What is the application of this method in everyday life?

FILTRATION:

- Put the funnel on the conical flask.
- Fold the filter paper in to four equal parts forming the shape of a funnel.
- Open one end of the filter paper and put it inside the funnel.
- Pour the mixture of the muddy dirty water iside the funnel.
- What can you observe?
- Note the colour of the water in the conical flask.

QUESTIONS:

1 What is in the funnel?
2 Why is it that only the water molecules pass through the filter paper?
3 Give examples of filtration apparatus we use at home.
4 What is the application in everyday life?

EVAPORATION

- Fill the evaporating dish with the salt solution.
- Place the water- bath on the tripod stand with the fire source.
- Place the evaporating dish on the water bath
- Watch as the water evaporates leaving the salt in the evaporating dish.

QUESTIONS:

1 What happens if the mixture is heated directly?
2 Explain what happens to the solvent?
3 What is the application in everyday life?

SEPARATING FUNNEL METHOD:

- Clamp the separating funnel on the retort stand.
- Close the tap and fill it with the mixture of water and oil.
- What do you observe?
- The mixture separates into two distinct layers.
- Open the tap and allow the water to drain into a beaker.
- Close the tap and drain the oil into another container.

OUESTIONS:

1 Is there any difference in the densities of the two liquids?
2 What happens if the densities are equal?
3 What is the application in everyday life?

APPENDIX 1C

Laboratory Problem-Solving Model (LAPSOM) Instructional Guide on Quantitative Analysis

The teacher teaches the student the background information.

There are two beakers containing two unknown solutions. The students are asked to identify each solution using red and blue litmus papers. Acid turns blue litmus paper red while Base turns red litmus paper blue. The students are asked to define an acid , The definition is written as – An acid is a substance which produces hydrogen ions (or protons) as the only positive ion when dissolved in water. There are two classes of acids namely organic acids and mineral or inorganic acids. They are asked to give examples of these acids. Examples of organic acids are Ethanoic acid in vinegar, Lactic acid in milk, citric acid in lime, lemon, and vitamin C. While the inorganic acids are Hydrochloric acid from hydrogen and chlorine, tetraoxosulphate(VI) acid , trioxonitrate(V) acid . Strong acid ionize completely in water to give hydrogen ions which is positively charged or cations and negatively charged ions or anions

e.g hydrochloric acid $HCL \longrightarrow H^+ + CL^-$.

While weak acids are only partially ionized in water

e.g ethaonic acid $HCOOH \longrightarrow COO^- + H^+$.

if a large quantity of water is added to a small quantity of acid, the resulting acid solution is dilute. If a little quantity of water is added to a relatively large quantity of acid, the solution of the acid will be concentrated. The solution that turns blue litmus paper to red is an acid.

Bases and Alkalis: The term base was originally used to describe substances that turned red litmus to blue and neutralized the properties of acids in aqueous solutions e.g oxides and hydroxides of metals Na_2O, K_2O, MgO. Most metallic oxides are insoluble in water, while some dissolve in water to form hydroxide

$$Na_2O_{(s)} + H_2O_{(l)} \longrightarrow 2NaOH_{(aq)}$$

Sodium oxide sodium hydroxide

A soluble basic hydroxide is known as alkali. A strong alkalis ionize completely in aqueous solutions to produce negatively charged hydroxide ions, OH^-, and positively charged metallic ions e.g sodium and potassium hydroxides while weak alkali produce relatively few ions e.g calcium hydroxide. The two solutions in the beakers are poured into a bigger container and tested with litmus paper. The solution formed has no effect on litmus paper, which means it is neutral to litmus. This shows that when acid and alkali react together salt and water are formed, which is neutral to litmus paper and the reaction is known as Neutralization. Acid + Base ⟶ Salt + water

e.g $HCL_{(aq)} + NaOH_{(aq)} \rightarrow Na^{+}CL^{-}{}_{(aq)} + H_2O_{(L)}$.

Neutralization is a process in which an acid reacts completely with an appropriate amount of alkali (or any other base) to produce a salt and water only

Neutralization can also be defined as the combination of hydrogen ions, H^+ and hydroxide ions OH, to form water molecules, H_2O. A salt is formed at the same time.

So a base can be defined as a substance which will neutralize an acid to yield a salt and water only.

The acidity and alkalinity of substances are measured using a scale of numbers from 0 to 14 known as the pH scale. A solution with a pH value of 7 is neutral i.e neither acidic nor alkaline. A solution with a pH value less than seven is acidic, while a value more than seven is alkaline. Acidity increases with decreasing pH, values while alkalinity increases with increasing pH values.

Acid- base indicators are dyes which change colour according to the pH of the medium, Each indicator has its own specific pH range over which it changes. The pH of a solution can be measured by using universal indicator and pH meter.

Indicator	Methyl Orange	Litmus	Phenolphthalein
pH range Colour change	3.1- 4.6 Orange	5.0- 8.0 Purple	8.3- 10.00 Pale Pink
Acid medium	Red	Red	Colourless
Alkaline medium	Yellow	Blue	Pink

Titration is the method employed in volumetric analysis. In this method, a solution which is the acid from a graduated vessel is added to a known volume of a second solution, the base in a conical flask until the chemical reaction between the two is just completed. This is shown by a colour change of the indicator in the resulting solution. In any titration a standard solution which is one with a known accurate concentration must be used to react with a solution of unknown concentration. The reacting volumes of the solutions are then used to calculate the unknown concentration of the solution. The concentration of a solution is the amount of solute in a given volume of the solution. It can be expressed as $moldm^3$ or gdm^3. The concentration of a solution in $moldm^3$ is the molar concentration. A molar solution of a compound is one which contains one mole or the molar mass of the compound in one dm^3 of the solution. For example the molar mass of sodium hydroxide is 40g/mol, therefore a molar solution of sodium hydroxide contains 1 mole or 40g of the hydroxide in $1dm^3$ of the solution.

Formulae for the calculations involving volumetric analysis.

$$\frac{\text{Concentration of acid } C_a}{\text{Concentration of base } C_B} \text{ X } \frac{\text{Volume of acid } V_A}{\text{Volume of base } V_B} = \frac{\text{Number of moles of acid}}{\text{Number of moles of base}} \quad \frac{n_a}{n_b}$$

$$\frac{C_A V_A}{C_B V_B} = \frac{n_a}{n_b}$$

$$\text{Number of moles of a substance} = \frac{\text{Number of particles}}{6.02 \ \text{x}10^{23}} = \frac{N}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\text{Number of moles of a substance} = \frac{\text{Volume}(cm^3)}{1000} \text{ x Concentration in } moldm^{-3} \ldots\ldots\ldots(2)$$

$$\text{Number of moles of a substance} = \frac{\text{Mass of substance in gm}}{\text{Molecular mass}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\text{Concentration in } moldm^{-3} = \frac{\text{Concentration in } gdm^{-3}}{\text{Molecular mass}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Sources of error and Precaution.

- Rinse the burette and pipette with the solution to be used in them to avoid diluting with the remains of water used in them.
- Air bubbles must be removed from the burette and pipette, to obtain accurate volume of solution.
- Never rinse the titration flask or conical flask with the solution it is to hold, to avoid using more solution than required.
- Do not blow the last drop at the tip of the pipette to avoid using volume than the pipette is constructed to deliver.
- The burette tap must be tight to avoid leakage.
- Remove the funnel from the burette before titration commences to avoid an increase in volume of the solution in the burette.
- Clamp the burette in a vertical position to avoid error due to parallax while taking the burette reading.

- Shake titration flask during titration to obtain a homogenous solution.
- Place the titration flask on a white surface to avoid over-shooting the end- point.

STAGE 1: Recognize the problem.

The students are given the laboratory manual which consists of stages 1-5 of the model.

a The students should recognize that the problem posed is the aim of each experiment.
b Read carefully the laboratory manual.
c Identify the apparatus provided.
d Check the soundness of the apparatus.
e Read the instruction again.
f Sketch the diagram of how you intend to arrange the apparatus to solve the problem.

STAGE 2: Recall background information.

(b) List the sources of error and precautions to be taken in each experiment.

STAGE 3: Conduct the Experiment.

- Wash the conical flasks, burette, pipette and beakers properly with soap solution and rinse with distilled water first, then with the solution to be poured inside each one except the conical flask.
- Drain all the washed apparatus.
- Fill the burette with the acid to the zero mark.
- Pipette the base into the conical flasks and add one or two drops of indicator.(methyl orange).
- Record the initial volume of the acid.
- Open the tap of the burette and run the acid into the conical flask containing the base.
- Shake the mixture to make a homogenous solution until there is a colour change.
- Read the acid level in the burette and record as final level of acid.
- Deduct the two readings and record as the volume of acid used.
- Repeat the experiment three more times.

	Titration Reading.Cm^3	1	2	3
Final burette reading. (Cm^3)	A			
Initial burette reading. (Cm^3)	B			
Volume of Acid used. (Cm^3)	X = A-B.			

Volume of Base solution = 25.00 / 20.00 cm^3

Mean volume of acid used = X cm^3

a. Write the equation of the reaction.

b. Write your observations.

QUESTIONS:

1. Why do we need to clean the pipette, burette, and conical flasks?
2. Why do we rinse the pipette and conical flask with the base and the burette with the acid?
3. What is the purpose of the indicator in the experiment?
4. What is the volume of acid used each time?
5. How would you obtain the number of moles taking part in the reaction?
6. What is the mole ratio of the acid or base?
7. Derive an expression for the concentration in mol/dm^3 of the acid.

APPENDIX IIA

Hands-on and Minds-on Problem-Solving Model (HAMPSOM) Instructional Guide on Nature of Matter

STAGE 1A: Problem Perception

The teacher writes the aim of the experiment which is the problem.

STAGE 1B: Acquiring related theory

The teacher asks the following questions.

What is matter?

What is it made up of?

He allows them to answer the questions

He explains that matter is anything that has weight and occupies space. It is made up of discrete particles, such as atoms and molecules. An atom is the smallest particle of an element which can take part in chemical reaction.

The teacher asks the following questions:

What is a molecule?

What is a compound?

He allows them to answer the questions

He then explains that a molecule is the smallest particle of a substance that can normally exist alone and still retains the chemical properties of that substance either an element or compound. Elements combine to form compounds while atoms combine to form molecules.

The teacher asks the following questions:

What is a physical change?

What is a chemical changes?

He allows the students to answer.

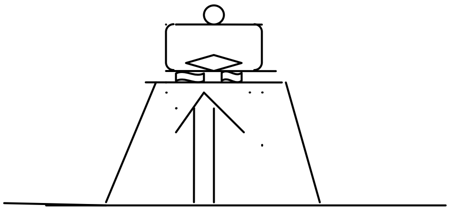
He explains that a physical change is one which is easily reversed and in which no new substances are formed.

The teacher asks them to classify the following into physical and chemical changes

Salt + water ⟶ salt solution

Wood ⟶ ash + gases

DIAGRAM



STAGE 1C: Planning experiments

Using the diagram the students should:

(a) identify the apparatus for the experiment.

(b)Label the apparatus in the diagram.

(c) Check the soundness of these apparatus.

(d) Students should write the sources of error and the precautions to be taken.

Teacher assists the students

STAGE 2A: Recalling theory

Students should

(a) Write down the general principle and laws.

(b) Recall the sources of error.

STAGE 2B: Performing Experiment or Practical

Method or Procedure:

Students should

Weigh the crucible with the lid.

Clean magnesium ribbon with sandpaper.

Cut 15cm of clean magnesium ribbon into the crucible.

Weigh the crucible with lid and Magnesium ribbon

Place the crucible on the tripod stand, heat strongly and remove the lid at intervals with the tong.

When the magnesium has burned completely, remove the lid and continue heating for two minutes.

Remove the crucible from the tripod stand and keep in a desiccator.

Weigh the crucible, content and lid when it is completely cold.

Repeat heating for three minutes. Allow the crucible, content and lid to cool then weigh again.

STAGE 3A: Observation:

Students should record all observations. The teacher goes round to correct those who are not following the instructions.

RESULT:

Mass of crucible and lid=
Mass of crucible, lid and magnesium =
Mass of crucible, lid and content after heating =
Mass of content =
Mass of magnesium =
Mass of oxygen =

QUESTIONS:

1) Name the elements involved in the experiment?
2) Name the compound formed?
3) What is the mass of crucible and lid?
4) Why do we need to clean the magnesium ribbon?
5) Why do we need to lift the lid when the magnesium was burning?
6) Why do we need to continue to heat the crucible for another 2 minutes?
7) What makes the magnesium change color?
8) What supports the burning of magnesium?
9) What is the name of the new substance?
10) How would you find out the mass of magnesium and mass of the magnesium oxide.
11) If the relative atomic mass of magnesium is 24 and oxygen is 16, how many atoms of Magnesium were used?
12) How many atoms of oxygen were used?
13) What is the ratio of atoms of magnesium to oxygen?
14) Derive the formula for the magnesium oxide?
15) Does the experiment involve physical or chemical change? Give reason for your answer?
16) What have you learnt from the experiment which is applicable to everyday life?
17) Is there any reason for repeating the experiment and why?

Teacher assists the students

APPENDIX IIB

HANDS-ON AND MIND-ON PROBLEM-SOLVING MODEL (HAMPSOM) INSTRUCTIONAL GUIDE on Separation Techniques

STAGE 1A: Problem Perception.

The teacher writes the aim of the experiment which is the problem. Separation techniques- sublimation, filtration, evaporation and separating funnel method.

STAGE 1B: Acquiring Related Theory

The teacher asks the students to explain mixture.

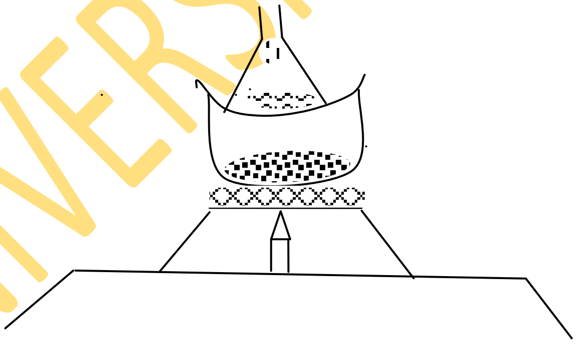
He allows them to answer.

He then explains to them that mixtures contain two or more different substances. Each constituent of a mixture still retains its individual properties. We can take advantage of these characteristics to separate mixtures. Thus the technique employed in separating mixtures makes use of the physical properties of their constituents.

SUBLIMATION: The teacher asks the students to state the three states of matter.

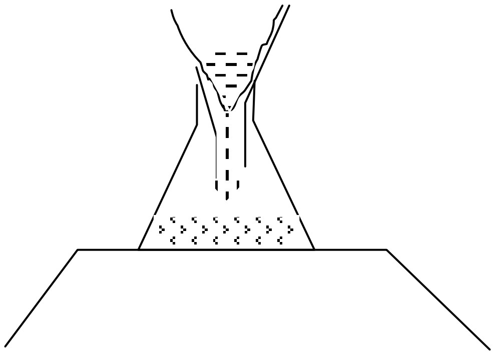
He asks them to explain the change of state from one form to another. He explains to them that sublimation is the direct conversion of a solid to the gaseous state directly without changing to the liquid state. Asks the students to write examples on the board. He gives example of camphor.

Diagram



FILTRATION: The teacher asks the students to explain filtration and give examples. After listening to their explanation of the students, he explains to them that filtration is used to separate an insoluble solid from a liquid. This involves the use of a filter paper which is porous in nature and allows the passage of only water which is the filtrate, while the particles remain in the funnel as residue. Industries such as water purification plant and breweries use filtration to remove solid particles from liquids. Also in the purification of pipe-borne water, the water strains through the various layers of the filter bed, leaving all forms of suspended materials behind. The filtered water is then treated with chemicals to kill any bacteria in it before being piped to the consumers.

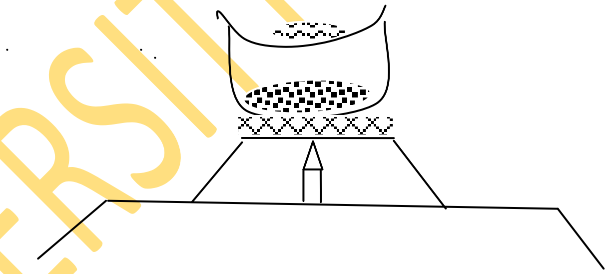
Diagram:



EVAPORATION TO DRYNESS: This method can be used to recover a solid solute from a solution, the solvent escapes into the atmosphere as vapour leaving the solute in the evaporating dish.

Solution ⟶ solute + solvent

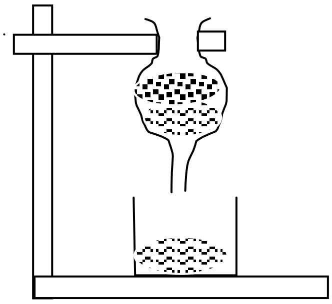
Diagram:



Evaporation can be done at a steady rate using a water bath or a sand bath. This method cannot be used to recover salts that are easily destroyed by heating. This method is used in salt making industries. Sea water is pumped into trenches and allowed to evaporate under the heat of the sun along the western coast of Africa. All the water dries up leaving behind the salt.

SEPARATING FUNNEL METHOD: He explains to them that some liquids do not mix together these are known as immiscible liquids e.g water and oil, water and petrol. Those that mix together to form a homogenous liquid are called miscible liquids e.g water and alcohol. The immiscible form two distinct layers when added together, a separating funnel can be used to separate the two layers into two different containers, the lower denser layer is collected before the less dense upper layer.

Diagram:



STAGE 1C: Planning Experiments.

(a) Using the diagrams the students should identify the apparatus for each experiment.

(b) Label the diagrams.

(c) Check the soundness of these apparatuses

(d) Students should write the sources of error and the precautions to be taken in each experiment.

Teacher assists the students

STAGE 2A: Recalling Theory.

Students should

(a) Write down the general principles and laws necessary for solving the problem.

(b) Recall the sources of error and take necessary precaution.

Stage 2B: Performing Experiment or Practical.

SUBLIMATION:

Students should

- Pour the mixture to be separated for example sodium chloride (NaCl) and Iodine (I_2) in an evaporating dish.
- Cover with an inverted funnel and heat indirectly on a water bath.
- Note what happens to the iodine.
- Scrape off the iodine into a Petri dish.

Teacher assists the students

PRECAUTIONS:

Avoid gas leakage during heating.

Be very careful when removing the funnel, so that the iodine does not mix with the sodium chloride.

QUESTIONS

1 Why do we heat indirectly on a water bath?

2 Why do we cover with inverted funnel?

3 What is the application of this method in everyday life

Teacher assists the students

FILTRATION:

Students to

- Put the funnel on the conical flask.
- Fold the filter paper in to four equal parts forming the shape of a funnel.
- Open one end of the filter paper and put it inside the funnel.
- Pour the mixture of the muddy dirty water inside the funnel.
- What can you observe?
- Note the colour of the water in the conical flask.

QUESTIONS:

1 What is in the funnel?

2 Why is it that only the water molecules pass through the filter paper?

3 Give examples of filtration apparatus we use at home.

4 What is the application in everyday life?

Teacher assists the students

EVAPORATION

- Fill the evaporating dish with the salt solution.
- Place the water- bath on the tripod stand with the fire source.
- Place the evaporating dish on the water –bath
- Watch as the water evaporates leaving the salt in the evaporating dish.

Teacher assists the students

QUESTIONS:

1 What happens if the mixture is heated directly?

2 Explain what happens to the solvent?

3 What is the application in everyday life?

SEPARATING FUNNEL METHOD:

- Clamp the separating funnel on the retort stand.
- Close the tap and fill it with the mixture of water and oil.
- What do you observe?
- The mixture separates into two distinct layers.
- Open the tap and allow the water to drain into a beaker.
- Close the tap and drain the oil into another container.

Teacher assists the students

QUESTIONS:

1 Is there any difference in the densities of the two liquids?
2 What happens if the densities are equal?
3 What is the application in everyday life?

Teacher assists the students

APPENDIX IIC

HANDS-ON AND MINDS-ON PROBLEM-SOLVING MODEL (HAMPSOM) INSTRUCTIONAL GUIDE on Quantitative Analysis

STAGE 1A: Problem Perception.

The teacher writes the topic which is volumetric analysis or quantitative analysis.

1B: Acquiring related theory.

The teacher teaches the students.

There are two beakers containing two unknown solutions. The students are asked to identify each solution using red and blue litmus papers. Acid turns blue litmus paper red while Base turns red litmus paper blue.

The students are asked to define an acid, the definition is written as – An acid is a substance which produces hydrogen ions (or protons) as the only positive ion when dissolved in water. There are two classes of acids namely organic acids and mineral or inorganic acids. They are asked to give examples of these acids. Examples of organic acids are Ethanoic acid in vinegar, Lactic acid in milk, citric acid in lime, lemon, and vitamin C. While the inorganic acids are Hydrochloric acid from hydrogen and chlorine, tetraoxosulphate(VI) acid , trioxonitrate(V) acid . Strong acid ionize completely in water to give hydrogen ions which is positively charged or cations and negatively charged ions or anions e.g hydrochloric acid $HCL \longrightarrow H^+ + CL^-$

While weak acids are only partially ionized in water e.g ethaonic acid $HCOOH \rightarrow COO^- + H^+$, if a large quantity of water is added to a small quantity of acid, the resulting acid solution is dilute. If a little quantity of water is added to a relatively large quantity of acid, the solution of the acid will be concentrated. The solution that turns blue litmus paper to red is an acid.

Bases and Alkalis: The teacher asks the students explain bases and alkalis. He explains to them that the term base was originally used to describe substances that turned red litmus to blue and neutralized the properties of acids in aqueous solutions e.g oxides and hydroxides of metals Na_2O, K_2O, MgO. Most metallic oxides are insoluble in water, while some dissolve in water to form hydroxide

$$Na_2O_{(s)} + H_2O_{(l)} \longrightarrow 2NaOH_{(aq)}$$

Sodium oxide ⟶ sodium hydroxide

A soluble basic hydroxide is known as alkali. A strong alkalis ionize completely in aqueous solutions to produce negatively charged hydroxide ions, OH^-, and positively charged metallic ions e.g sodium and potassium hydroxides while weak alkali produce relatively few ions e.g calcium hydroxide.The two solutions in the beakers are poured into a bigger container and tested with litmus paper. The solution formed has no effect on litmus paper, which means it is neutral to litmus. This shows that when acid and alkali react together salt and water are formed, which is neutral to litmus paper and the reaction is known as Neutralization. Acid + Base → Salt + water

e.g $HCL_{(aq)} + NaOH_{(aq)} \longrightarrow Na^+CL^-_{(aq)} + H_2O_{(L)}$.

Neutralization is a process in which an acid reacts completely with an appropriate amount of alkali (or any other base) to produce a salt and water only.

Neutralization can also be defined as the combination of hydrogen ions, H^+ and hydroxide ions OH^- to form water molecules, H_2O. A salt is formed at the same time.

So a base can be defined as a substance which will neutralize an acid to yield a salt and water only.

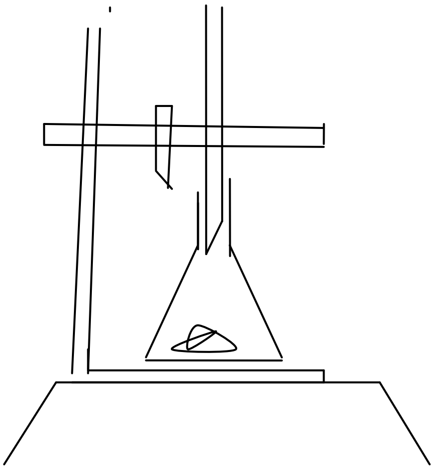
The acidity and alkalinity of substances are measured using a scale of numbers from 0 to 14 known as the pH scale. A solution with a pH value of 7 is neutral i.e neither acidic nor alkaline. A solution with a pH value less than seven is acidic, while a value more than seven is alkaline. Acidity increases with decreasing pH, values while alkalinity increases with increasing pH values.

He explains that acid- base indicators are dyes which change colour according to the pH of the medium, Each indicator has its own specific pH range over which it changes. The pH of a solution can be measured by using universal indicator and pH meter.

Indicator	Methyl Orange	Litmus	Phenolphthalein
pH range	3.1- 4.6	5.0- 8.0	8.3- 10.00
Colour change	Orange	Purple	Pale Pink
Acid medium	Red	Red	Colourless
Alkaline medium	Yellow	Blue	Pink

Titration is the method employed in volumetric analysis. In this method, a solution which is the acid from a graduated vessel is added to a known volume of a second solution, the base in a conical flask until the chemical reaction between the two is just completed. This is shown by a colour change of the indicator in the resulting solution. In any titration a standard solution which is one with a known accurate concentration must be used to react with a solution of unknown concentration. The reacting volumes of the solutions are then used to calculate the unknown concentration of the solution. The concentration of a solution is the amount of solute in a given volume of the solution. It can be expressed as moldm^3 or gdm^3. The concentration of a solution in moldm^3 is the molar concentration. A molar solution of a compound is one which contains one mole or the molar mass of the compound in one dm^3 of the solution. For example the molar mass of sodium hydroxide is 40g/mol, therefore a molar solution of sodium hydroxide contains 1 mole or 40g of Sodium hydroxide in 1dm^3 of the solution.

Diagram:



Formulae for the calculations involving volumetric analysis.

$$\frac{\text{Concentration of acid } C_a}{\text{Concentration of base } C_B} \times \frac{\text{Volume of acid } V_A}{\text{Volume of base } V_B} = \frac{\text{Number of moles of acid} \quad n_a}{\text{Number of moles of base} \quad n_b}$$

$$\frac{C_A V_A}{C_B V_B} = \frac{n_a}{n_b}$$

Number of moles of a substance = $\frac{\text{Number of particles}}{6.02 \times 10^{23}} = \frac{N}{L}$ ……………………………..(1)

Number of moles of a substance = $\frac{\text{Volume(cm}^3\text{)}}{1000}$ x Concentration in moldm^{-3}………..(2)

Number of moles of a substance = $\frac{\text{Mass of substance in gm}}{\text{Molecular mass}}$ …………………(3)

Concentration in moldm^{-3} = $\frac{\text{Concentration in gdm}^{-3}}{\text{Molecular mass}}$ ……………..... (4)

STAGE 1C: Planning experiment.

a Label the diagram.

b Using the diagram the students should identify the apparatus for the experiment.

c Check the soundness of these apparatus.

d Students should write the sources of error and the precautions to be taken.

Teacher assists the students

STAGE 2A: Recalling theory.

a. Recall the sources of error and take the necessary precautions.
b. The teacher asks them to mention these sources of error and the precautions.
c. He writes the sources of error and asks the students to write those that were not included in their list.

Sources of error and Precaution.

- Rinse the burette and pipette with the solution to be used in them to avoid diluting with the remains of water used in them.
- Air bubbles must be removed from the burette and pipette, to obtain accurate volume of solution.
- Never rinse the titration flask or conical flask with the solution it is to hold, to avoid using more solution than required.
- Do not blow the last drop at the tip of the pipette to avoid using volume than the pipette is constructed to deliver.
- The burette tap must be tight to avoid leakage.
- Remove the funnel from the burette before titration commences to avoid an increase in volume of the solution in the burette.
- Clamp the burette in a vertical position to avoid error due to parallax while taking the burette reading.
- Shake titration flask during titration to obtain a homogenous solution.
- Place the titration flask on a white surface to avoid over shooting the end- point.

d. The teacher asks them to write the aim of the experiment which is the problem.

STAGE 2B: Performing Practical

- Wash the conical flasks, burette, pipette and beakers properly with soap solution and rinse with distilled water first, then with the solution to be poured inside each one except the conical flask.
- Drain all the washed apparatus.
- Fill the burette with the acid to the zero mark.

- Pipette the base into the conical flasks and add one or two drops of indicator (methyl orange).
- Record the initial volume of the acid.
- Open the tap of the burette and run the acid into the conical flask containing the base.
- Shake the mixture to make a homogenous solution until there is a colour change.
- Read the acid level in the burette and record as final level of acid.
- Deduct the three readings and record as the volume of acid used.

Titration Reading. (Cm^3)		1	2	3
Final burette reading. (Cm^3)	A			
Initial burette reading. (Cm^3)	B			
Volume of Acid used. (Cm^3)	X = A-B.			

Volume of NaOH solution = $25.00cm^3$

Mean volume of acid used = X cm^3

Equation of reaction: $HCL + NaOH \rightarrow NaCl + H_2o$.

STAGE 3: OBSERVATION:

Students should record their observation.

The teacher goes round to check their readings

QUESTIONS:

1. Why do we need to clean the pipette, burette, and conical flasks?
2. Why do we rinse the pipette and conical flask with the base and the burette with the acid?
3. What is the purpose of the indicator in the experiment?
4. What is the volume of acid used each time?
5. How would you obtain the number of moles taking part in the reaction?
6. What is the mole ratio of the acid or base?
7. Derive an expression for the concentration in mol/dm^3 of the acid.

Teacher assists the students

APPENDIX IIIA

CONVENTIONAL METHOD (CONTROL) INSTRUCTIONAL GUIDE on Nature of Matter

The teacher teaches the students the background information first.

The teacher asks the following questions.

What is matter and what is it made up of?

He explains that matter is anything that has weight and occupies space. It is made up of discrete particle, such as atoms and molecules. An atom is the smallest particle of an element which can take part in chemical reaction.

The teacher asks the questions;

What are a molecule and a compound?

The teacher explains that a molecule is the smallest particle of a substance that can normally exist alone and still retain chemical properties of that substance either an element or compound. Elements combine to form compounds while atoms combine to form molecules.

The teacher asks the following question;

What are physical and chemical changes? The teacher explains that a physical change is one which is easily reversed and in which no new substances are formed.

Classify these into physical and chemical changes.

Salt + water ⟶ salt solution

Wood ⟶ ash +gases

The teacher explains the following to the students

METHOD OR PROCEDURE

Weigh the crucible with the lid.

Clean magnesium ribbon with sandpaper.

Cut 15cm of clean magnesium ribbon into the crucible.

Place the crucible on the tripod stand, heat strongly and remove the lid at intervals with the tong.

When the magnesium has burned completely, remove the lid and continue heating for two minutes.

Remove the crucible from the tripod stand and keep in a desiccator.

Weigh the crucible, content and lid when it is completely cold.

Repeat heating for three minutes. Allow the crucible, content and lid to cool then weigh again.

OBSERVATION: Students should record all observations.

Repeat the experiment again and calculate the average of the figures.

RESULT:

Mass of crucible and lid=

Mass of crucible, lid and magnesium =

Mass of crucible, lid and content after heating =

Mass of content =

Mass of magnesium =

Mass of oxygen =

The teacher asks the students the following questions

(a) Write down known general principles and mathematical expressions that are necessary for solving the problem.

(b) List possible sources of error in solving the problem.

(c) Recognize independent and dependent variables in the problem and note their relationship.

QUESTIONS:

1) Name the elements involved in the experiment?
2) Name the compound formed?
3) What is the mass of crucible and lid?
4) Why do we need to clean the magnesium ribbon?
5) Why do we need to lift the lid when the magnesium was burning?
6) Why do we need to continue to heat the crucible for another 2 minutes?
7) What makes the magnesium change color?
8) What supports the burning of magnesium?
9) What is the name of the new substance?
10) How would you find out the mass of magnesium and mass of the magnesium oxide?
11) If the relative atomic mass of magnesium is 24 and oxygen is 16, how many atoms of magnesium were used?.
12) How many atoms of oxygen were used?
13) What is the ratio of atoms of magnesium to oxygen?
14) Derive the formula for the magnesium oxide?
15) Does the experiment involve physical or chemical change?
    Give reason for your answer?
16) What have you learnt from the experiment which is applicable to everyday life?
17) Is there any reason for repeating the experiment and why?

APPENDIX IIIB

CONVENTIONAL METHOD (CONTROL) INSTRUCTIONAL GUIDE on Separation Techniques

The teacher teaches the students the following

Mixtures contain two or more different substances. Each constituent of a mixture still retains its individual properties. We can take advantage of these characteristics to separate mixtures. Thus the technique employed in separating mixtures makes use of the physical properties of their constituents.

SUBLIMATION: Asks the students to state the states of matter. This is the direct conversion of a solid to the gaseous state directly without changing to the liquid state. Asks the students to write examples on the board. Gives example of camphor.

FILTRATION: This is used to separate an insoluble solid from a liquid. This involves the use of a filter paper which is porous in nature and allows the passage of only water which is the filtrate, while the particles remain in the funnel as residue. Industries such as water purification plant and breweries use filtration to remove solid particles from liquids. Also in the purification of pipe-borne water, the water strains through the various layers of the filter bed, leaving all forms of suspended materials behind. The filtered water is then treated with chemicals to kill any bacteria in it before being piped to the consumers.

EVAPORATION TO DRYNESS: This method can be used to recover a solid solute from a solution, the solvent escapes into the atmosphere as vapour leaving the solute in the evaporating dish.

Solution → solute + solvent

Evaporation can be done at a steady rate using a water bath or a sand bath. This method cannot be used to recover salts that are easily destroyed by heating. This method is used in salt making industries. Sea water is pumped into trenches and allowed to evaporate under the heat of the sun along the western coast of Africa. All the water dries up leaving behind the salt.

SEPARATING FUNNEL METHOD: Some liquids do not mix together; these are known as immiscible liquids e.g water and oil, water and petrol. Those that mix together to form a homogenous liquid are called miscible liquids e.g water and alcohol. The immiscible liquids form two distinct layers when added together, a separating funnel can be used to separate the two layers into two different containers, the lower denser layer is collected before the less dense upper layer.

The teacher explains the following with or without diagrams

SUBLIMATION:

- Pour the mixture to be separated for example sodium chloride (NaCl) and Iodine (I_2) in an evaporating dish.
- Cover with an inverted funnel and heat indirectly on a water bath.
- Note what happens to the iodine.
- Scrape off the iodine into a Petri dish.

PRECAUTIONS:

Avoid gas leakage during heating.
Be very careful when removing the funnel, so that the iodine does not mix with the sodium chloride.

QUESTIONS

1 Why do we heat indirectly on a water bath?

2 Why do we cover with inverted funnel?

3 What is the application of this method in everyday life.

FILTRATION:

- Put the funnel on the conical flask.
- Fold the filter paper in to four equal parts forming the shape of a funnel.
- Open one end of the filter paper and put it inside the funnel.
- Pour the mixture of the muddy dirty water iside the funnel.
- What can you observe?
- Note the colour of the water in the conical flask.

QUESTIONS:

1 What is in the funnel?
2 Why is it that only the water molecules pass through the filter paper?
3 Give examples of filtration apparatus we use at home.
4 What is the application in everyday life

EVAPORATION

- Fill the evaporating dish with the salt solution.
- Place the water- bath on the tripod stand with the fire source.
- Place the evaporating dish on the water –bath
- Watch as the water evaporates leaving the salt in the evaporating dish.

QUESTIONS:

1 What happens if the mixture is heated directly?
2 Explain what happens to the solvent?
3 What is the application in everyday life?

SEPARATING FUNNEL METHOD:

- Clamp the separating funnel on the retort stand.
- Close the tap and fill it with the mixture of water and oil.
- What do you observe?
- The mixture separates into two distinct layers.
- Open the tap and allow the water to drain into a beaker.
- Close the tap and drain the oil into another container.

OUESTIONS:

1 Is there any difference in the densities of the two liquids?
2 What happens if the densities are equal?
3 What is the application in everyday life?

APPENDIX IIIC

CONVENTIONAL METHOD (CONTROL) INSTRUCTIONAL GUIDE on Quantitative Analysis

The teacher teaches the student the following.

There are two beakers containing two unknown solutions. The students are asked to identify each solution using red and blue litmus papers. Acid turns blue litmus paper red while Base turns red litmus paper blue. The students are asked to define an acid , The definition is written as – An acid is a substance which produces hydrogen ions (or protons) as the only positive ion when dissolved in water. There are two classes of acids namely organic acids and mineral or inorganic acids. They are asked to give examples of these acids. Examples of organic acids are Ethanoic acid in vinegar, Lactic acid in milk, citric acid in lime, lemon, and vitamin C. While the inorganic acids are Hydrochloric acid from hydrogen and chlorine, tetraoxosulphate(VI) acid , trioxonitrate(V) acid . Strong acid ionize completely in water to give hydrogen ions which is positively charged or cations and negatively charged ions or anions

e.g hydrochloric acid HCL $\longrightarrow$ $H^+ + CL^-$.

While weak acids are only partially ionized in water

e.g ethaonic acid HCOOH $\longrightarrow$ $COO^- + H^+$, if a large quantity of water is added to a small quantity of acid, the resulting acid solution is dilute. If a little quantity of water is added to a relatively large quantity of acid, the solution of the acid will be concentrated. The solution that turns blue litmus paper to red is an acid.

Bases and Alkalis: The term base was originally used to describe substances that turned red litmus to blue and neutralized the properties of acids in aqueous solutions e.g oxides and hydroxides of metals Na_2O, K_2O, Mg. Most metallic oxides are insoluble in water, while some dissolve in water to form hydroxide

$$Na_2O_{(s)} + H_2O_{(l)} \longrightarrow 2NaOH_{(aq)}$$

Sodium oxide sodium hydroxide

A soluble basic hydroxide is known as alkali. A strong alkalis ionize completely in aqueous solutions to produce negatively charged hydroxide ions, OH^-, and positively charged metallic ions e.g sodium and potassium hydroxides while weak alkali produce relatively few ions e.g calcium hydroxide.

The two solutions in the beakers are poured into a bigger container and tested with litmus paper. The solution formed has no effect on litmus paper, which means it is neutral to litmus. This shows that when acid and alkali react together salt and water are formed, which is neutral to litmus paper and the reaction is known as Neutralization. Acid + salt $\longrightarrow$ water

e.g $HCL_{(aq)} + NaOH_{(aq)} \longrightarrow Na^{+}CL^{-}_{(aq)} + H_2O_{(L)}$.

Neutralization is a process in which an acid reacts completely with an appropriate amount of alkali (or any other base) to produce a salt and water only.

Neutralization can also be defined as the combination of hydrogen ions, H^+ and hydroxide ions OH^-, to form water molecules, H_2O. A salt is formed at the same time.

So a base can be defined as a substance which will neutralize an acid to yield a salt and water only.

The acidity and alkalinity of substances are measured using a scale of numbers from 0 to 14 known as the pH scale. A solution with a pH value of 7 is neutral i.e neither acidic nor alkaline. A solution with a pH value less than seven is acidic, while a value more than seven is alkaline. Acidity increases with decreasing pH, values while alkalinity increases with increasing pH values.

Acid- base indicators are dyes which change colour according to the pH of the medium, Each indicator has its own specific pH range over which it changes. The pH of a solution can be measured by using universal indicator and pH meter.

Indicator	Methyl Orange	Litmus	Phenolphthalein
pH range Colour change	3.1- 4.6 Orange	5.0- 8.0 Purple	8.3- 10.00 Pale Pink
Acid medium	Red	Red	Colourless
Alkaline medium	Yellow	Blue	Pink

Titration is the method employed in volumetric analysis. In this method, a solution which is the acid from a graduated vessel is added to a known volume of a second solution , the base in a conical flask until the chemical reaction between the two is just completed. This is shown by a colour change of the indicator in the resulting solution. In any titration a standard solution which is one with a known accurate concentration must be used to react with a solution of unknown concentration. The reacting volumes of the solutions are then used to calculate the unknown concentration of the solution. The concentration of a solution is the amount of solute in a given volume of the solution. It can be expressed as $moldm^3$ or gdm^3. The concentration of a solution in moldm^3 is the molar concentration. A molar solution of a compound is one which contains one mole or the molar mass of the compound in one dm^3 of the solution. For example the molar mass of sodium hydroxide is 40g/mol, therefore a molar solution of sodium hydroxide contains 1 mole or 40g of the hydroxide in 1dm^3 of the solution.

Formulae for the calculations involving volumetric analysis.

$$\frac{\text{Concentration of acid } C_a}{\text{Concentration of base } C_B} \times \frac{\text{Volume of acid } V_A}{\text{Volume of base } V_B} = \frac{\text{Number of moles of acid } n_a}{\text{Number of moles of base } n_b}$$

$$\frac{C_A V_{A.}}{C_B V_B} = \frac{n_a}{n_b}$$

$$\text{Number of moles of a substance} = \frac{\text{Number of particles}}{6.02 \times 10^{23}} = \frac{N}{L} \qquad \text{………………..(1)}$$

$$\text{Number of moles of a substance} = \frac{\text{Volume(cm}^3)}{1000} \times \text{Concentration in moldm}^{-3} \qquad \text{…..(2)}$$

$$\text{Number of moles of a substance} = \frac{\text{Mass of substance in gm}}{\text{Molecular mass}} \qquad \text{………………(3)}$$

$$\text{Concentration in moldm}^{-3} = \frac{\text{Concentration in gdm}^{-3}}{\text{Molecular mass}} \qquad \text{…………..... (4)}$$

Sources of error and Precaution.

- Rinse the burette and pipette with the solution to be used in them to avoid diluting with the remains of water used in them.
- Air bubbles must be removed from the burette and pipette, to obtain accurate volume of solution.
- Never rinse the titration flask or conical flask with the solution it is to hold, to avoid using more solution than required.
- Do not blow the last drop at the tip of the pipette to avoid using volume than the pipette is constructed to deliver.
- The burette tap must be tight to avoid leakage.
- Remove the funnel from the burette before titration commences to avoid an increase in volume of the solution in the burette.
- Clamp the burette in a vertical position to avoid error due to parallax while taking the burette reading.
- Shake titration flask during titration to obtain a homogenous solution.

- Place the titration flask on a white surface to avoid over-shooting the end- point.

The teacher asks the students to do their titration and answer the questions

Titration Reading. (Cm^3)		1	2	3
Final burette reading. (Cm^3)	A			
Initial burette reading. (Cm^3)	B			
Volume of Acid used. (Cm^3)	X = A-B.			

Volume of Base solution = 25.00 / 20.00 cm^3

Mean volume of acid used = X cm^3

a Write the equation of the reaction.

b Write your observations.

QUESTIONS:

1. Why do we need to clean the pipette, burette, and conical flasks?
2. Why do we rinse the pipette and conical flask with the base and the burette with the acid?
3. What is the purpose of the indicator in the experiment?
4. What is the volume of acid used each time?
5. How would you obtain the number of moles taking part in the reaction?
6. What is the mole ratio of the acid or base?
7. Derive an expression for the concentration in mol/dm^3 of the acid.

APPENDIX 1V

ANSWERS TO QUESTIONS IN APPENDICES A

1 Magnesium and Oxygen

2 Magnesium Oxide

3 This depends on the mass obtained in each of the experimental group because we have different sizes of crucible.

4 We need to clean the dust and impurities on the magnesium ribbon so as not to increase the mass.

5 We need to lift the lid when the magnesium is burning so that air which contains oxygen can flow into the crucible.

6 We need to continue to heat the crucible for another two minutes after it has burnt completely, so that the magnesium oxide will be free of other gases present in the air.

7 The colour changed because the magnesium ribbon has combined with oxygen to form another compound which is magnesium oxide.

8 Oxygen supported the burning of magnesium.

9 The name of the new substance is magnesium oxide.

10 The mass of the magnesium can be obtained from subtracting the mass of crucible and lid from the mass of crucible lid and magnesium.

The mass of the magnesium oxide can also be obtained by subtracting the mass of crucible with lid from the mass of crucible, lid and content after heating.

11- 14 These can be calculated using the masses obtained during the experiment.

15 The experiment involves a chemical change, because the magnesium oxide produced is different from the magnesium ribbon and the magnesium ribbon can not be obtained again.

16 From the experiment we can derive the formula of magnesium oxide. This shows that oxygen is present in the air sustaining the life of animals without which we cannot be alive. The oxygen is not only used for breathing by animals but can combine with other elements and form another product.

17 There is need to repeat the experiment if there is no change in colour and mass of magnesium ribbon. This shows that the reaction between magnesium and oxygen has not occurred or there is a faulty apparatus.

APPENDIX V

ANSWERS TO QUESTIONS IN APPENDICES B

SUBLIMATION

1 We need to heat indirectly on a water bath so that we do not loose some of the materials when the heating is direct and too much.

2 We covered the evaporating dish with an inverted funnel so that the rate at which the gas is escaping can be reduced at the narrow end of the funnel which leads to condensation of the gas. This allows us to regain our iodine instead of escaping into the atmosphere.

3 At home we make use of elements and compounds which change from solid directly to gas for example camphor. The odour in gaseous state send away cockroaches and other insects that can destroy our books, dresses and food away.

FILTRATION

1 The residue which is the solid particle (solute) is in the funnel.

2 Only the solvent passes through the filter paper, because the solute is bigger in size than the pores of the filter paper.

3 Examples of filtration apparatus used at home are sieve with pores of different sizes and clean cloth.

4 We can use the method to remove suspended particles from our water, also can be used to remove big particles from our yam flour, cassava flour, pap and stones from food items.

EVAPORATION

1If the mixture is heated directly the rate of evaporation will increase and some of salt can be lost when evaporation is almost completed.

2 The solvent changes to gaseous state and the molecules escape into the atmosphere.

3 Application everyday life is that when we cook or fry food, we should not use high flame. Also if there is too much water in the food or soup, we can concentrate or remove the water by evaporation. It is also useful in the industries.

SEPARATING FUNNEL METHOD

1 Yes there is difference in the densities of the two liquids

2 We will use another method for the separation.

3 If we mistakenly pour two liquids together e.g palm oil or ground nut oil with water or kerosene with water. We can easily separate them due to their differences in density. We can carefully pour each into different containers not necessarily using the separating funnel. It is also used in industries.

APPENDIX V1

ANSWERS TO QUESTION IN THE APPENDICES C

1 We need to wash the apparatuses because of impurities which can affect the volume of acid used.

2 These are the solutions that should be poured in to these apparatuses.

3 The indicator changes colour at the end point (showing the end of the reaction).

4 The volume of the acid used is the subtraction of the initial volume of the burette from the final reading of the burette.

5 This is from a balanced equation of the reaction.

6 This is the ratio of the mole of the acid to the mole of the base in the balanced equation of the reaction.

7 $C_A \; V_A / C_B \; V_B = N_A / N_B$

$$C_A \; V_A \; N_B = C_B \; V_B \; N_A$$

$$C_A = C_B \; V_B \; N_A / \; V_A \; N_B$$

Where

C_A = concentration of Acid in mol/dm^3

C_B = concentration of Base in mol/dm^3

V_A = volume of the Acid in cm^3 obtained during titration

V_B = volume of the Base in cm^3 this is the volume of the pipette

N_A = the number of moles of the acid obtained from the balanced equation of the reaction

N_B = the number of moles of the base obtained from the balanced equation of the reaction

8 This is useful mostly in the industries where precise amount of substances are needed.

APPENDIX V11

INTERNATIONAL CENTRE FOR EDUCATIONAL EVALUATION
INSTITUTE OF EDUCATION
UNIVERSITY OF IBADAN
IBADAN.

CHEMISTRY ACHIEVEMENT TEST (CAT)

Dear Respondent,

This test is for research purposes. Please shade the appropriate answer lettered A-D to each question in the answer sheet provided. Thank you.

1. The relative molar mass of Magnesium(II) tetraoxosulphate(VI) is A.72 B.120 C.140 D.240 (Mg=24, S=32,O=16)

2. In which of these equations will the number of molecules of reactant and products remain the same?

A. $Ag\ NO_3 + BaCl_2 \longrightarrow AgCl + Ba(NO_3)$
B. $Fe + H_2O \longrightarrow Fe_3O_4 + H_2O$
C. $CaCO_3 \longrightarrow CaO + CO_2$
D. $H_2S + O_2 \longrightarrow H_2O + SO_2$

3. A compound has a chemical formula $M_2(SO_4)_3$. The combining power of M is A.6, B. 5, C.3, D.2

4. What is the percentage by mass of Calcium in Calcium trioxocarbonate (IV)?
(Ca=40, C=12, O=16). A. 80%, B.58% , C. 52%, D.40%.

5. The chemical formula for zinc oxides is
A. ZnO_2, B. Zn_2O_2, C. Zn_2O, D. ZnO.

6. $CuSO_4.\ 5H_2O$ means
A. 1 atom Cu, 1 atom of S, 5 atoms of O and 2 atoms of H.
B. 1 atom of Cu, 1 atom of S, 9 atoms of O and 2 atoms of H.
C. 1 atom of Cu, 1 atom of S, 5 atoms of O and 10 atoms of H.
D. 1 atom of Cu, 1 atom of S, 9 atoms of O and 10 atoms of H.

7. Silver Oxide was heated strongly to produce Silver and Oxygen. The chemical equation for the reaction
is: A $2Ag_2O \longrightarrow Ag + O_2$
B. $2Ag_2O \longrightarrow 4Ag + O$
C. $2Ag_2O \longrightarrow 2Ag_2 + O$
D. $2Ag_2\ O \longrightarrow 4Ag + O_2$

8. A compound with empirical formula CH_2O and a molecular formula of 90 g mo1-1. What is the molecular formula of the compound? (C=12, H=1, O=16)

A. $3CH_2O$ B. $C_3H_6O_3$ C. $(CH_2O)_3$ D. $C_3(H_2O)_3$.

9. 7g of iron reacts with 8g of Sulphur to form Iron(11) Sulphide. Calculate how much of Sulphur was left unused ? The equation of the reaction is : $Fe + S \longrightarrow FeS$ (Fe = 56, S = 32). A. 2, B. 3, C. 4, D. 6.

10. A solution of sodium trioxocarbonate (1V) contains 10.6g in 250cm^3 of solution. Calculate the concentration of the solution. [Na_2CO_3 = 106.0].

A. 0.4 mol/dm^3, B. 1.0 mol/dm^3, C. 10.6 mol/dm^3, D.25.0 mol/dm^3.

11. The numerical coefficients in a balanced equation give A. the number of moles of reactants and products, B. the molar mass of the reactants and products, C. the number of moles reactants Only, D. the molar mass of the products only.

12.The number 0f moles of SO_4^{2-} in K_2SO_4. $Cr_2(SO_4)_3$. $24H_2O$ is A. 4, B. 5, C, 6, D. 8.

13. How many moles of copper ions (Cu^{2+}) are there in 0.2 mol CuSO4 ?.

$CuSO_4 \longrightarrow Cu^{2+} + SO_4^{2-}$ A, 0.1, B. 0.2, C. 0.4, D. 2.0.

14. In a chemical reaction one mole of Fecl3 solution reacts completely with 3 moles of NaOH solution. What volume of 1M NaOH solution will be required by 50cm^3 of 1M Fecl$_3$ solution.

A. 150cm^3, B. 100cm^3, C. 50cm^3, D. 25cm^3.

15. What is the mass in gram of solute in 1M NaCl?. (Na = 23, CL = 35.5).

A. 585g. B, 58.5g, C. 5.85g, D. 0.585g.

16. Vaseline does not flow like kerosene because: A. Vaseline particles are thicker than kerosene particles. B. Vaseline particles form a solid at room temperature. C. Vaseline particles are held closer than kerosene. D. Vaseline particles are heavier than kerosene.

17. Iron fillings can be separated from chalk particles by

A. Magnetization, B. Decantation, C. counting, D. blowing.

18. Sieving method is employed in

A. gari industry, B. soap Industry, C. salt making industry, D. gas industry.

19. Components of crude oil are best separated by

A. Fractional distillation B. Fractional crystallization C. Distillation D. Evaporation.

20. A mixture of sand and iodine can be separated by

A. filtration B. sublimation C. crystallization, D. sedimentation.

21. The component colours of a leaf can be separated by

A. colour extraction, B. centrifugation, C. boiling, D. chromatography.

22. A mixture of salt and sand can be separated by

A. dissolution, filtration and evaporation, B, Filtration, dissolution and evaporation

C. evaporation, dissolution and filtration, D, Dissolution, evaporation and filtration.

23. Which of the following techniques is used in town water supply?

A Crystallization B. filtration C. distillation D. fractional distillation.

24 The process of spinning insoluble solute in a solution at high speed is called

A. Distillation, B. spinning, C. centrifugation, D. magnetization.

25. The apparatus needed in a filtration process include

A. Conical flask, funnel, filter paper, B. beaker, funnel, sieve, C. Conical flask, funnel, sieve, D. beaker, funnel, filter paper

26. One of the following is not a criteria for purity

A. Atomicity, B. density, C. boiling point, D. melting point.

27. A mixture in which the constituents can easily be distinguished is said to be

A. Homogenous, B. miscible, C. Heterogeneous, D. Immiscible,

28. Principles which separation of mixtures are based include the following except

A. particle size, B. atomic mass, C. magnetic property, D. solubility.

29. When a solid body is heated it expands. Which is the most satisfactory explanation?

A. the molecules get bigger, B. the heat energy is converted into extra mass,

C. the space between the molecules increases, D. the molecular vibration decreases.

30. How many mole of $AgNO_3$ are there in 500 cm^3 of 0.01M $AgNO_3$ solution ?.

A. 5 mole, B. 0.5 mole, C. 0.05 mole, D. 0.005 mole.

APPENDIX V111

ANSWERS TO THE CHEMISTRY ACHIEVEMENT TEST

1. **B**
2. **C**
3. C
4. D
5. D
6. D
7. D
8. B
9. C
10. A
11. A
12. A
13. C
14. A
15. B
16. C
17. A
18. A
19. A
20. B
21. D
22. A
23. B
24. C
25. A
26. A
27. C
28. B
29. C
30. D

APPENDIX 1X

INTERNATIONAL CENTRE FOR EDUCATIONAL EVALUATION,

INSTITUTE OF EDUCATION, U. I. IBADAN.

STUDENTS' ATTITUDETO PRACTICAL CHEMISTRY SCALE (SAPCS)

Dear Respondent,

This questionnaire is for research purpose. Please tick where you feel it is appropriate. Thank you.

Please note: **SA** means Strongly Agree; **A** means Agree; **D** means Disagree

SD means Strongly Disagree

School:………………………………………………………………………………………

……………………………………

Number in class: ……………..

ITEMS	SA	A	D	SD
1 The chemistry class is always boring.				
2 It is interesting reading chemistry topics than working problems.				
3 When a problem cannot be solved immediately, it is better to keep solving it until ones gets it.				
4 It is good to play games that help in solving problems in practical chemistry.				
5 When challenged by situations one cannot immediately understand, one should try to read to solve the problem.				
6 Solving different types of problems is interesting.				
7 Games which demand rigorous thinking are bad.				
8 Most of my friends are as good as myself in solving problems.				
9 When a question is left unanswered in the class, one should continue thinking about it.				
10 It is better to have a friend who can tell you the solution to a difficult problem than to work it out yourself.				
11 Puzzle books are interesting you find it difficult to leave it once you pick it up.				
12 keeping record of games when others are playing is enjoyable.				

13 Mathematics is one of my best subject.				
14 When instructions are not very clear, one should find a way to solve the problem				
15 Thinking about problems is my hobby.				
16 Chemistry practical is too mathematical for my liking.				
17 It is enjoyable working with different chemistry apparatus.				
18 One does not need much practical chemistry to have a good grade in Chemistry.				
19 Linking theory with practical is very easy.				
20 It is better for the teacher to demonstrate experiments than students performing it.				
21 Minimum instruction should be given in solving practical chemistry problem.				
22 Instructions in the practical manual should be followed strictly.				
23 A good knowledge of chemistry practical, shows good knowledge of chemistry.				
24 Students who participate in practical chemistry develop interest in chemistry.				
25 Previous knowledge is needed to solve problems in practical chemistry.				
26 It is important to understand problem before solving it in practical chemistry.				
27 One should review the related principles of the problem problems in practical chemistry.				
28 A job that needs thinking is better than one which does not need thinking.				
29 The teacher’s experiment demonstration helps develop interest in chemistry practical.				
30 The Technological progress could not be without practical chemistry.				

APPENDIX X

QUESTIONS ON THE PRACTICAL FOR THE CHEMISTRY PROCESS SKILL RATING SCALE (CPSRS)

All your burette readings initial and final must be recorded

A is a solution containing 1.04g HCl per 500cm^3 of solution. **B** was prepared by diluting 50.0cm^3 of a saturated solution of NaOH at room temperature to 1000cm$^{3.}$

a Put **A** into the burette and titrate it against 25cm^3 portion of **B** using methyl orange as indicator. Repeat the titration to obtain consistent titres. Tabulate your results and calculate the average volume of acid used.

b From your results and the information provided above , calculate the

i concentration of **A** in mol/dm^3

ii concentration of **B** in mol/dm^3

The equation of the reaction is:

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

[H= 1, O = 16, Na = 23, Cl = 35.5]

APPENDIX X1

INTERNATIONAL CENTRE FOR EDUCATIONAL EVALUATION

INSTITUTE OF EDUCATION ,UNIVERSITY OF IBADAN, IBADAN.

CHEMISTRY PROCESS SKILLS RATING SCALE(CPSRS).

Key

V - Very Poor
P - Poor
F - Fair
G - Good
E - Excellent

Skill Category	Behaviour Category	VP	P	F	G	E
A.Manipulative Skills and conduct of experiments	i Adherence to instructions to carry out a full range of experiments/ activities.					
	ii Use of relevant/ correct apparatus(es) for given activities.					
	iii Correct handling of apparatus.					
	Iv Use of reasonable time to set up experiment					
	v Set up of experiment accurately					
	vi Ability to discharge drops					
B.Controlling Extraneous Variables	i Adopt strategies to prevent uncontrolled changes in the amount of measured materials during experiment,(through leaking, spilling)					
	ii Wash up apparatuses to prevent contamination and misleading observation.					
	iii Use only two drops of indicator to avoid masking of end point during titration experiment.					
	iv Record measured quantities accurately.					
	v Use average titre values for calculations during volumetric analysis.					

C. Measurement skills	i Select correct measuring instrument/ apparatus for measuring a given substance.					
	ii Estimate quantity of chemical substances (volumes, masses)					
	iii Accurately read the liquid in burette or measuring cylinder.					
	iv Accurately pipette the liquid into the conical flask.					
D. Work Habit	i Self reliance in carrying out experiment.					
	ii Honestly record observation/ data.					
	iii Self reliance in analysis of data.					
	iv Neatness of report.					
	v Wash up apparatus after use.					
	vi keep work space orderly.					
	vii Dispose waste/ effluents correctly(solid wastes in trash basket and liquids in the sink).					
	viii keep laboratory clean.					
E. Safety Skill	i Adopt strategies to avoid exposing self or mate to laboratory accident.					
	ii Adopt organized movement in the laboratory.					
	iii Avoid obstruction of passage way for free movement of students/ staff.					
	iv Avoid damage/ accident to laboratory apparatus					
F.Mathematics	i Ability to find average of repeated quantitative data e.g titre values.					
	ii Understand the basic formulae for computation of concentrations.					
	iii Set up relevant mathematical equations relating known and unknown.					
	iv Ability to effect changes of subject in a mathematical equation in order to find the					

	unknown.					
	v Ability to substitute data that has been generated from experiment into equation.					
	Vi Details and accuracy of computations.					
	vii Adjust values to suitable significant figures					
H.Observation, Recording of data andcommunication	i Use correct units of measure to express quantities.					
	ii Recognise end point/ equivalent point of titration experiment.					
	iii Organise data in the in the appropriate tabular format.					
	iv Record Data/ Observation accurately.					

APPENDIX X11

ANSWER TO THE QUESTIONS ON CHEMISTRY PROCESS SKILLS SCALE

The students were rated as they perform the titration. The titre value is the same for each experimental group and different from other groups. This is because the sources of water and the chemicals are different.

Calculations.

i Concentration of **A** in mol/dm^3

From the question 1.04g of HCl per 500 cm^3

This means that 500 cm^3 contains 1.04g

1000cm^3 will contain 1000/500 x 1.04 = 2.08g/dm^3

Concentration in mol/dm^3 = Concentration in g/dm^3/ molecular mass.

Molecular mass of HCl = 1+ 35.5 = 36.5 g/mol

Concentration in mol/dm^3 = 2.08/ 36.5 = 0.0569

Concentration of **B** in mol/dm^3

$$C_A\ V_A / C_B\ V_B = N_A / N_B$$

$$C_A\ V_A\ N_B = C_B\ V_B\ N_A$$

$$C_B = C_A\ V_A\ N_B / V_B\ N_A$$

Where

C_A = concentration of Acid in mol/dm^3

C_B = concentration of Base in mol/dm^3

V_A = volume of the Acid in cm^3 obtained during titration

V_B = volume of the Base in cm^3 this is the volume of the pipette

N_A = the number of moles of the acid obtained from the balanced equation of the reaction

N_B = the number of moles of the base obtained from the balanced equation of the reaction

$C_A\ V_A / C_B\ V_B = N_A / N_B$

$0.0569 \times V_A / C_B \times 25 = 1/1$

$C_B = 0.0569 \times V_A \times 1/25 \times 1$

This was be calculated for each experimental group when the value of the average volume of acid used was obtained for each group and substituted.

APPENDIX X111

INTERNATIONAL CENTRE FOR EDUCATIONAL EVALUATION

INSTITUTE OF EDUCATION ,UNIVERSITY OF IBADAN, IBADAN.

LABORATORY INVENTORY CHECK LIST (LICL).

Dear Sir/Ma,

This is for research purposes. Please tick ( ) the appropriate column for the availability of the apparatus in your school. Thank you.

Name of school:……………………………………………………………………………….

Qualifications:…………………………………………………………………………………

Number of years spent in the school:……………………………………….

APPARATUS	AVAILABLE	NOT AVAILABLE
1 Flat bottomed flask		
2 Round bottomed flask		
3 Conical flask		
4 Test tubes		
5 Boiling tubes		
6 Beakers		
7 Evaporating dishes		
8 Separating funnel		
9 Funnels		
10 Filter papers		
11 Retort stands		
12 Glass rods		
13 Tripod stands		
14 Bunsen burner		
15 Gas (any source of heat)		
16 Liebig’s condenser		
17 Crucible with lid		
18 Pipe clay triangle or wire gauze		
19 Micro test tubes		
20 Combustion tube		
21 U tube		

22 Thistle funnel		
23 Connecting tubes		
24 Weighing balance		
25 Ethanol		
26 Sodium chloride		
27 Magnesium ribbon		
28 Mineral Acids: HCL,H_2SO_4		
29 Bases: NaOH, Na_2CO_3.		

6

APPENDIX X1V

PHOTOGRAPHS OF STUDENTS WORKING IN THE LABORATORY DURING THE RESEARCH