EFFECTS OF TWO PROBLEM-SOLVING INSTRUCTIONAL STRATEGIES ON STUDENTS' ACHIEVEMENT AND SCIENCE PROCESS SKILLS IN BIOLOGY PRACTICAL

BY

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DEDICATION

This work is dedicated to:

The Holy Trinity: God the Father, God the Son and the Holy Spirit.

And to

My grand children

Eseose and Genose Omokhogbe.

ABSTRACT

The prevailing poor performance of students in biology is linked to their poor involvement in practical activities in biology as well as teachers' use of instructional strategies that do not promote acquisition of science process skills. Many earlier studies on problem solving instructional strategies aimed at addressing students' poor performance in biology did not involve the students' production of instructional materials needed for practical activities. In order to ascertain the effects of problem-solving instructional strategy on students' performance, it is useful to conduct a study that involves students using instructional materials they produced themselves. This study, therefore, determined the effects of two problem-solving instructional strategies (Bio Problem-Solving Instructional Strategy which involved the use of produced instructional materials and Gayford Problem-Solving Heuristics) on students' achievement and science process skills in biology practical.

The study adopted a pretest-posttest control group experimental design with a 3 x 3 x 2 factorial design. The sample consisted of 828 students from nine randomly selected co-educational Senior Secondary Schools from three local government areas in Ibadan. Three schools each were assigned to two experimental and one control groups and the study lasted twelve weeks. The instruments used were: Achievement Test in Biology Practical (r=0.84), Science Process Skills Test (r=0.81), Mental Ability Test (r=0.86, Science Process Skills Assessment Inventory. In addition, Teachers' Guide on Problem Solving Instructional Strategy, Teachers' Guide on Modified Lecture Method and Guidelines for Evaluating Teachers' Performance were used for training teachers. Seven null hypotheses were tested at 0.05 level of significance. Data were analysed using ANCOVA and Pairwise Comparison Post hoc test.

There was significant main effect of treatment on students' achievement in biology practical ($F_{(2,809)}$ =14.8; $p<.05$). Students exposed to Bio Problem-solving Instructional Strategy ($\bar{X}$ =19.7) and Gayford Problem-Solving Heuristics ($\bar{X}$= 19.7) performed better than those in the Control group ($\bar{X}$= 17.9) in the Biology Practical achievement test. There was a significant main effect of treatment on science process skills in biology practical $F_{(2,809)}$ =182.4, $p<.05$. Students exposed to Bio Problem-Solving Instructional Strategy ($\bar{X}$= 42.8) performed better than those in Gayford Problem-Solving Heuristics ($\bar{X}$= 33.7) and control group ($\bar{X}$= 26.6) in science process skills test. Mental ability had significant main effect on students' science process skills ($F_{(2,809)}$= 18.3; $p<.05$). Students of high mental ability ($\bar{X}$=37.0) performed better than the medium ability group ($\bar{X}$= 34.5) and low ability group ($\bar{X}$= 31.6). The interaction effects of treatment and mental ability on students' achievement ($F_{4,809}$ =4.2; $p<.05$) and on science process skills, ($F_{(4,809)}$ =5.7; $p<.05$) were significant.

Problem solving instructional strategies improved the performance of the students in biology practical with Bio Problem-Solving Instructional Strategy having more impact on students' science process skills in biology as well as providing greater transfer of learning to medium and low ability students. The use of materials produced by the students helped them to gain better understanding of the concepts taught and enhanced their level of acquisition of science process skills in biology. Therefore, teachers should employ problem solving instructional strategy in biology practical lessons.

Key words: Science process skills, Biology practical, Mental ability, Problem-solving instructional strategy, Instructional material production.

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CERTIFICATION

I certify that this research work was carried out by Mrs Esther Ahuose Ehikhamenor in the Department of Teacher Education, University of Ibadan, Nigeria.

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LIST OF ABBREVIATIONS

FRN:	Federal Republic of Nigeria
WAEC:	West African Examination Council
SSCE:	Senior School Certificate Examination
STAN:	Science Teachers' Association of Nigeria
BioPSOM:	Bio Problem Solving Model
BioPSIS:	Bio Problem-Solving Instructional Strategy
GPSH:	Gayford Problem-Solving Heuristics
ACER:	Australian Council for Educational Research
ATPB:	Achievement Test in Biology Practical
REPSOM:	Researcher's Experimental Problem Solving Model.
PBL:	Problem-Based Learning
SS2:	Secondary School 2
ANCOVA:	Analysis of Covariance
NISP:	Nigerian Integrated Science Project
NISSSP:	Nigerian Secondary School Science Project
UNICEF:	United Nations International Children Emergency Fund
UNESCO:	United Nations Educational and Scientific Organization
NECO:	National Examination Council
SPST:	Science Process Skills Test
SPSAI:	Science Process Skills Assessment Inventory

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Problem

Science is an invaluable enterprise which any nation that wants to advance technologically should depend upon. Science is not only an organized body of knowledge of the physical world but also a method of inquiry which makes use of intellectual and process `skills that can enhance students' performance. Man has employed the application of science to improve the quality of life. 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 (Afolabi and Audu, 2007; Afolabi, Oniyide and Audu, 2008). Olagunju, Adesoji, Ireogbu and Ige (2003) had stressed the importance of science in national development and wealth creation. They believed that knowledge of science has "potentials in boosting national prestige, military might, national income and international status of the country". Today the economy and political strength of a nation is judged by how much it has achieved through scientific and technological advancement. Technology cannot thrive if science subjects are not encouraged in schools. This again underscores the fact that the future development of any nation in the fields of engineering, medicine and agriculture rests on how well the science subjects are taught.

The need for indigenous technology and industrial development has made the Federal Government of Nigeria to put in more emphasis on science education. The National Committee on Science Education Standards and Assessment (1992) has referred to science education as "one that must reflect science as it is practiced and that science education must prepare students who understand the modes of reasoning or scientific inquiry and can use them". This implies that effective science education does equip the learner with potentials and capabilities for self-actualization (Mkpa, 2001). The National Policy on Education (FRN 2004) states that the aim of science education is to “inculcate in the child the spirit of enquiry and creativity”. Akinbobola and Afolabi (2010) stated that for science teaching to be meaningful and relevant, the nature of science must be adequately reflected. Consequently, this calls for the shift of emphasis in science teaching from the traditional content and factual acquisition of scientific knowledge to those which make the learner actively involved in learning by doing. According to Orimogunje, 2008; Szent-Gyorgi (1994); Alridge (1992) and Lavoie (1992), improving students’ ability to reason logically, think critically and at the end solve problems that come their way in the environment is essentially a major aim of science education, Biology education inclusive.

Biology is a life science which is described as an “action subject” which goes beyond talking and listening (Ibe and Nwosu, 2003). This implies that the learner should study Biology by being actively involved in the teaching-learning process. It is applicable in all spheres of human careers particularly in the areas of agriculture, medicine, health, environmental studies (pollution and environmental degradation), biotechnology and nursing. It is a subject that has to do with various unifying principles, concepts, and processes that enables students to face the challenges that confront them in life. Besides, Biology enables the learner to possess reasonable and functional scientific attitudes that help the learner to be well integrated in the immediate environment as well as a functional unit of the larger community. In addition, the study of Biology has generated crucial facts that have made the logical basis for genetic counselling and the determination of a child’s paternity possible. Biology is an inquiry oriented subject to which practical work plays an invaluable role. It is a subject that engages students in varied science process skills such as observing carefully, classifying, interpreting, predicting events, designing experiments, organizing information, reporting completely and accurately.

The National Policy on Education (FRN, 2004) stipulates that each secondary school student should study at least a science subject. Biology is classified as one of the core subjects that should be offered by students at the senior secondary school examination (FRN, 2004). A credit pass in Biology is a pre- requisite for admission into Nigerian

Universities for the study of Medicine, Biochemistry, Microbiology and Pharmacy. This implies that Biology is an essential science subject in the Nigerian school system. A number of teaching instructional strategies have been adopted by teachers in secondary schools for Biology instruction. Prominent among them are: Advance organisers, Discovery method, Concept mapping, Lecture method and Demonstration method. However, reports from past results of students at Biology examinations have shown that students perform poorly, (Ndioho, 2007; Odubunmi, 2006; Adesemowo, 2005 and Orukotan, 1999). Table 1.1 shows students' grades in Biology in Senior Secondary Certificate Examination from 2004 to 2011.

Table 1.1: Distribution of Students' Grades in Senior Secondary Certificate Examination (SSCE) in Biology from 2004 – 2011

Year	**Total SAT**	**NUMBER AND PERCENTAGE OBTAINING GRADE**								
		CREDIT AND ABOVE						**Total Credit**	**PASS**	**FAIL**
		1	**2**	**3**	**4**	**5**	**6**	**1 – 6**	**7 – 8**	**9**
2004 %	1005894 *97.85*	164 *0.01*	1074 *0.10*	24492 *2.43*	46378 *4.61*	48682 *4.83*	177765 *17.67*	298555 *29.68*	326092 *32.41*	348890 *34.68*
2005 %	1051557 *98.03*	241 *0.02*	970 *0.09*	36820 *3.50*	35655 *3.39*	75404 *7.17*	226760 *21.56*	375850 *35.74*	313827 *29.84*	338491 *32.18*
2006 %	1137181 *97.86*	1872 *0.16*	7466 *0.65*	100324 *8.82*	84625 *7.44*	109380 *9.61*	256187 *22.52*	559854 *49.23*	292317 *25.70*	261200 *22.96*
2007 %	1238163 *98.11*	106 *0.01*	969 *0.08*	31560 *2.55*	43439 *3.51*	77387 *6.25*	259750 *20.98*	413211 *33.37*	397353 *32.09*	402148 *32.48*
2008 %	1259965 *98.05*	549 *0.04*	2278 *0.18*	42608 *3.38*	38123 *3.03*	81990 *6.51*	262096 *20.80*	427644 *33.94*	329961 *26.19*	484071 *38.42*
2009 %	1340206 *98.21*	207 *0.02*	1179 *0.09*	26168 *1.95*	34038 *2.54*	65049 *4.85*	256471 *19.1*	383112 *28.59*	413014 *30.82*	471312 *35.17*
2010 %	1300418 *98.11*	1515 *0.12*	8702 *0.67*	121451 *9.34*	74113 *5.70*	128342 *9.87*	311510 *23.95*	645633 *49.64*	318486 *24.49*	297228 *22.86*
2011 %	155199 *98.20*	128 *0.00*	1067 *0.07*	51247 *3.40*	49683 *3.30*	110823 *7.36*	366484 *24.34*	579432 *38.49*	458338 *30.45*	441720 *29.34*

Source: West African Examination Council (SSCE) Statistics of Entries and Results (2013). (Figures in italics represent percentages)

Table 1.1 reveals that students' performance in Biology has been very poor. From 2004 to 2011, less than half of the students who sat for Biology at the SSCE got a credit grade. In 2006, 49.23% of the students had a credit grade. This dropped to 33.7% in 2007 with a slight increase of 0.37% in 2008 (33.94%). This dropped to 28.59% in 2009 and rose up to 49.64% in 2010 with an increase of 15.70%. This however, was not sustained or improved upon but dropped to 38.49% in 2011. That same year, 29.34% of the students who sat for Biology had F9. The Table further reveals that the trend in students' performance in Biology has not changed over the years with greater percentage of students scoring below credit grade.

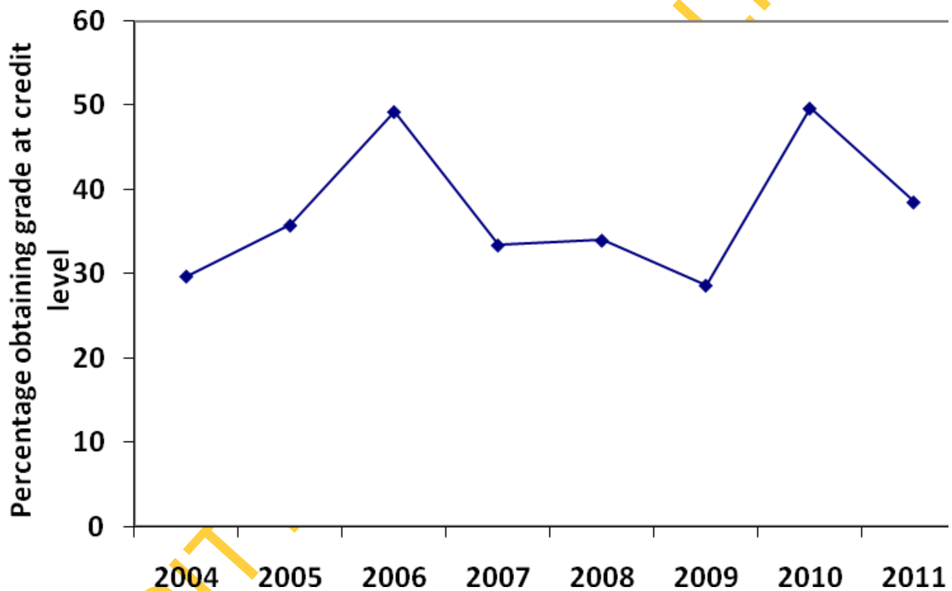


Fig 1.1: The Distribution of Students' Grades in SSCE in Biology from 2004-2011

The line graph (Fig 1.1) further depicts the trend of students' performance in SSCE, from 2004 to 2011. The graph shows that there was a gradual rise in performance from 2004 to 2006 (though the performance was below average). This dropped sharply in 2007 and continued in that trend to 2009. Students' performance however rose in 2010 but dropped again in 2011.

Poor performance of students has been attributed to lack of qualified teachers and inadequate practical equipment (Onyegegbu, 2001); the non-utilization of instructional resource materials by teachers, (Oriade, 2007; Ehikhamenor, 2003); inability of teachers to provide opportunities for students to apply theoretical knowledge of science concepts in practical situations (Onyegegbu 2006; Ige 1999, 2003; and Akale and Usman, 1993) and use of inadequate teaching strategies for understanding difficult concepts (Okoye and Okechukwu 2010; Okafor and Okeke, 2006). Also, students' failure has been found to result from their non- involvement in practical activities and project work that promote the spirit of inquiry, creativity and development of necessary skills and competences for functional living (Nwagbo, 2006, 2008; Ayogu, 2007 and STAN, 1992), and the use of instructional strategies that was still didactic and basically talk and chalk (Udogu, Ifeakor and Njelita, 2007).

Biology teaching must be accompanied with laboratory activities as emphasized in the objectives of the Biology syllabus. Biology practical skills are science process skills. They form part of the Biology curriculum which are taught during lessons. The West African Examination Council (WAEC) employs practical examination to find out how much Biology practical skills the students' have acquired. The practical paper is usually designed and set out to test candidates in the following:

1. power of observation;
2. ability to represent observation by illustration;
3. ability to relate forms with functions;
4. ability to recognize general characteristics of plants and animals;
5. interpretation of data which illustrate known biological principles;
6. ability to perform simple experiments and draw inferences from result and
7. acquisition of adequate laboratory and field skills necessary to carry out and evaluate experiments and projects in biology.

Practical work is an integral part of Biology. The objective of Biology syllabus emphasizes students' involvement in the learning process through practical activities in the classroom or in the laboratory. A number of practical activities are spelt out for the learner to which students are given opportunities to apply their theoretical knowledge of biological concepts and principles in practical situations. According to Edelson, Gordin and Pea (1999), students should be encouraged to learn how to conduct investigations the way scientist themselves conduct investigations. Reports from research studies have shown that students achieve greatly when the teaching and learning of science occurs 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 and Cossa, 2007). Similarly, 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 (Adane and Adams, 2011). Nzewi (2008) believes that practical activities should be carried out in such a way that it makes students engage in hands-on, minds-on activities employing varieties of instructional materials to make learning more meaningful.

The teaching and learning of Biology in secondary schools in Nigeria shows that very little practical activities are included in classroom lessons and that laboratory programmes are not always organized as an opportunity for exploration (Millar 2004; Agarkar, 1998). Students still learn mechanically or by rote expressing non- meaningful learning (Agbowuro, 2008; Ndioho, 2007; Ajewole, 2003; Noyak, 2002 and WAEC chief examiners reports, 1999-2011). The failure of teachers to employ appropriate strategies that incorporate practical activities into learning transaction probably may have contributed to students' poor performance in Biology. This, then calls for a pedagogical shift from teaching strategies which do not promote meaningful learning in students to learner-centred strategy, as it is being proposed in this study, which could help to enhance learners' achievement and the development of science process skills.

More emphasis is usually placed on the practical performance of students in determining their overall academic achievement as can be seen in the allocation of scores to the papers that make up the examination. Biology examination is structured into two (2) papers. Paper I is a practical test which carries 80 marks. Paper II consists of two parts, A and B. Part A is the multiple choice objective questions which carry 60 marks and Part B is the essay questions which carry 60 marks. The practical test is usually a test of the science process skills or practical skills which must have been acquired from the process of science.

Carpi and Egger, 2009 submits that process of science refers to the 'practices used in science to uncover knowledge and interpret meaning of those theories'. To Carpi and Egger, (2009), the process of science is robust, dynamic and diverse and goes beyond the scientific method. The scientific method is a way to ask and answer scientific questions by making observation and carrying out experiments. In other words, it is a way in which scientific experimentation and observation are carried out. The underlying skills and premises which govern the scientific method are referred to as science process skills (Geek, 2012).

Science process skills are a set of broadly transferable abilities and potentials appropriate to science discipline and reflective of true behaviour of scientist (Okeke, Akusoba, Okafor 2004). Gagne (1968) defines science process skills as intellectual skills and learned capabilities which scientists use as self-management procedure in carrying out scientific activities. This implies that science process skills are the processes scientists use in conducting science. These skills make it possible for students to carry out objective investigation and draw conclusions based on results. The need for students to develop science process skills through the process of problem solving in suitable environment has been emphasized by science educators (Okeke, Akusoba and Okafor, 2004; Lee, Goh and Chia, 1996). Science process skills promote logical and sequential problem solving which can be used in many aspect of school life (Webb, 2012). The development of these skills is basic to scientific inquiry and the development of intellectual skills needed to learn concepts (Ibe and Nwosu, 2003). Ibe and Nwosu also believed that the process skills can increase students' capabilities to answer questions and solve problems. Raimi and Fabiyi (2008); Awodi (1984) pointed out that science teachers cannot effectively teach science without the use of the process of science, neither can the students learn science outside the application of the process of science. This implies that gaining scientific knowledge should not be separated from the acquisition of science process skills rather, they should complement one another. Hence, the need to employ an instructional strategy that could enable students' acquire the necessary science process skills becomes paramount.

The American Association for the Advancement of Science (AAAS) considered science process skills as a set of intellectual skills that are associated with acquiring reliable information about nature. The AAAS classified the science process skills into fifteen. These are measuring, classifying, observing, predicting, communicating, inferring, using number, questioning, using space/time relationship, controlling variables, defining operationally, hypothesising, formulating models, designing experiment and interpreting data. Science process skills are organised hierarchically with the simplest leading into the complex ones. The hierarchical arrangement of science process skills puts the skills into two categories, namely, the basic science process skills and the integrated science process skills (American Association for Advancement of Science 1998; Ango, 1992; Padilla, Dillashaw and Okey 1983). The basic science process skills are measuring, classifying, communicating, using number, observing, inferring, using space/time relationship and questioning while the integrated science process skills are controlling and manipulating variable, hypothesising, defining operationally, formulating models, designing experiment and interpreting data. The basic science process skills provide a foundation on which the integrated science process skills are learnt.

This study considered manipulative, observation, communication and cognitive skills that students can acquire during problem solving of an experimental nature. Manipulative skills involve proper handling of apparatus, setting up of experiment as well as the preparation of instructional materials. Assessment on manipulative skills is based on direct observation of the students when they are doing laboratory work. Observational skills involve students' ability to observe what takes place during practical investigation. This involves the use of the senses. Communication skills are essential skills which involve the students' ability to represent findings of practical work in a logical manner with correct illustrations, assess their oral response to questions as well as students' ability to record results. Cognitive skills on the other hand, measure the basic understanding of the knowledge of science concepts in a practical test, for example, mammalian skeleton, absorption of water in plants and diffusion.

The need to assist students to develop science process skills is a crucial aspect of Biology teaching as this helps students carry out laboratory activities in a meaningful way. However, secondary school teachers pay very little attention to practical activities that can lead to the development of these skills (Okoli, 2006 and Adegoke, 2000). Raimi and Fabiyi, (2008), also observed that not much work has been carried out on students' acquisition of Biology practical skills. This implies that secondary school students do not possess sufficient science skills that can aid their problem solving skills. This may have been caused by the instructional strategies used in teaching and learning of Biology which probably do not promote the development of science process skills. This therefore suggests that a self-activity based teaching strategy which facilitates students' participation and active involvement in the learning process would be a viable option for addressing problems associated with students' lack of science process skills in Biology. This is what this study seeks to address.

Improving students' academic performance is the major concern of science educators. There is need to address this trend of students' poor performance and be able to produce scientific literate persons if we are to advance in science and technology. Therefore, to achieve this objective, effective teaching strategy such as problem solving strategy could be used to teach biological concepts. As far back as over three decades ago, Gagne (1980) believed that "the central point of education is to teach people to think, to use their rational powers, to become better problem solvers'. Similar to Gagne's belief, most psychologists and educators hold the view that problem solving is one of the most important cognitive activities in life. Furthermore, in Gagne's influential book, "The Conditions of Learning", problem solving was identified as the highest form of learning because it allows knowledge to be transferred to novel situations through the formation of schema. Problem solving results in the acquisition of new ideas that increases the applicability of principles previously learned (Gagne, 1965).

Problem solving has been regarded as the linking ties between context and application in a learning environment for the development of basic skills and their uses in various dimensions (Kirkley, 2003). Problem solving has been found to enable students integrate declarative knowledge with procedural knowledge which is capable of helping them develop the necessary skills for enhanced academic achievement (Okoye and Okechukwu, 2010; Raimi and Fabiyi, 2008; Ige, 1998; Cavallo, 1996). Also the use of well structured problem solving models in instruction is capable of facilitating students' development of practical skills (Ikitde, 1994; Onwioduokit, 1989). This assertion is to be verified in this study.

In the last three decades, some problem solving models emerged to address students' difficulties in practical Biology. Prominent among them include Henderson and Lally Problem Solving Chain (1988) which was effective for students' co-operative or team work, Gayford Problem Solving Heuristics (1989) used to assess students' group work, Researcher's Experimental Problem Solving Model, (Ikitde, 1994) for acquisition of students' experimental proficiency in Biology and Ige (2003) Inquiry Based Framework for practical problem solving. The instructional strategies from these models indicated steps or stages in problem solving process. A learner is expected to progress from one problem state to another until a solution is reached. The stages in these instructional strategies seem to have a general trend but the heuristic involved and the scope of applicability differ. Besides, some of the models are for group or individual practical work with or without the acquisition of practical skills. According to Orji (1998) a careful selection should be made in the choice of problem solving instructional strategy that will consist of all the fundamental phases basic to problem solving models. Consequently, a modified problem solving model which consists of five basic steps based on Researcher's Experimental Problem Solving Model (1994) was developed.

The modified model of problem solving used in this study is termed Bio Problem Solving Model (BioPSOM). It consists of the following: Recognition of problem; Gathering and processing of information; Experimentation (instructional material production, engaging in practical work, and observation); Analysis of results (report, draw and discuss result) and Evaluation. It is designed to assess individual student's work. The main distinctive feature in this model is the inclusion of production of instructional materials. The review of literature shows that a number of problem solving models have been developed and used to improve students' academic achievement and acquisition of science process skills but not much, if any at all, has been developed having a sub-step which involved the students producing the instructional materials they needed for laboratory activities as they engage in problem solving in Biology Practical.

Production of teaching and learning resources is an important and integral part of curriculum development. Teachers and students should be seen to be involved in the production of instructional materials that could be used to promote effective Biology teaching in schools. Students have tremendous role to play in the production of instructional materials as this make them to be part of the teaching and learning process. When students are taught with the instructional materials they themselves produce they understand biological concepts better (Ofoegbu, 2005). Students' involvement in the production of instructional materials with their teachers acting as guides is one crucial strategy that teachers should employ as this may foster experimental proficiency of students. These instructional materials can be produced before the commencement of the laboratory activities particularly if the material production would take a long time as obtained in the production of mammalian skeletal bones. Olagunju and Ojo, (2006) and Ehikhamenor, (2003) observed that instructional materials designed for teaching a particular concept make the students to understand the concept better. Students' involvement in the production of instructional materials may help them develop the ability to represent observation by illustration and to relate form to function. Also, students are able to gain first hand information and encounter scientific concepts in meaningful ways rather than depend on memorizing facts given to them by their teachers. Thus, building production of instructional materials into problem solving models, which is an innovation, might make the instructional strategy based on the model more effective in students' learning outcomes. This is to be verified in this study.

Also considered in this study is Gayford Problem-Solving Heuristics (GPSH). Gayford developed a 9-step strategy for solving experimental biological problems in a logical and stepwise approach. At each step, questions involving actions which the problem solver is expected to go through are asked. Gayford Problem-Solving Heuristics can be employed in the classroom and in the laboratory and, is effective in assessing students' group or co-operative work (Ikitde 1994). Several studies have been carried out using problem solving strategies but none has focussed on the use of problem solving instructional strategy where students used the instructional materials they produced before engaging in problem solving. Besides, the problem solving instructional strategies for this study

(Bio Problem-Solving Instructional Strategy and Gayford Problem-Solving Heuristic) have not been previously used for problem solving in Biology, neither did the literature reviewed indicate that a study on problem solving instructional strategy designed for students' individual work and co-operative work in Biology Practical had been carried out in Nigeria.

Tissues and Supporting Systems in Animals and Plants form one of the major practical contents of the senior secondary school Biology curriculum. West African Examination Council Chief Examiners' reports (1990, 1992, 1995, 1999, 2002 and 2005, 2011) emphasized the inability of students to answer practical questions drawn from the skeletal system correctly. The reports stated that students demonstrated the following inadequacies in answering the practical questions from the skeletal system.

(i) not drawing to proportion;

(ii) inability to draw relationship between parts;

(iii) inability to state magnification;

(iv) students' dependence on rote memory rather than understanding biological concepts to reason out solution.

These reports also emphasized that students have not sufficiently achieved the general objectives of the syllabus as it relates to the supporting tissues in animals. These objectives include students' ability to:

(i) demonstrate by experiment the supporting tissues using various materials provided

(ii) recognize different skeletal and supporting tissues

(iii) state the location and arrangement of skeletal and supporting tissues in animals

(iv) and describe the arrangement of supporting tissues.

These weaknesses which students exhibit at examinations may arise from either the use of inappropriate instructional strategies by teachers which do not encourage science process skills or practical skills acquisition or failure of students to interact adequately with instructional materials. None of the literature reviewed indicated that work has been carried out to address the weaknesses exhibited by students at Biology Practical examination using problem-solving instructional strategies that involved students' production of instructional materials. It is hoped that the weaknesses of students in achieving greatly in Biology can be overcome through the use of problem solving instructional strategies as it is proposed in this study.

Apart from possible influences of problem solving instructional strategies on students' achievement and science process skills in Biology, some internal factors which deal with learners' disposition to learn have been found to contribute to students' academic performance. Since the main focus of this study is to make the learner assume greater responsibility of his/her own learning, the factors or characteristics which seem to have more considerable effects on students learning are considered for this study. These are mental ability and gender.

Emphasis is being placed on learners to acquire higher order thinking skills and basic literacy skills which are in high demands in most sectors of human endeavours. Problem solving as a complex mental activity consists of a number of actions and cognitive skills. It consists of higher order skills such as "visualization, association, manipulation, abstraction, reasoning, comprehension, analysis, synthesis and generalization, each needing to be managed and coordinated" (Garafalo and Lister, 1985). Biology is concerned with conceptual thinking, visualization, abstraction, manipulation of apparatus and generalization of facts. These require the application of mental process. Mental process and science process skills are closely associated with science (Biology). Process skills can be acquired and developed when students are engaged in science instruction through practical work. Practical work as an integral part of Biology involves greater mental activities that require students' cognitive ability to be consistent with correct reasoning, ask reasonable questions, think critically, seek appropriate answers and solve problems and these depend on students' cognitive ability levels. Problem solving strategy has been found to be a method of instruction that can make students analyze, state problems clearly and follow a step-wise sequence in finding solution to the problem. This goes beyond making use of memorized facts. It involves high level of mental reasoning and ability. Falaye (2000) opined that students' ability to acquire knowledge, control information and recall what they have learnt is integrally related to learners' ability. Thus, knowing the mental ability of students (student variable) will help to ascertain if the mental ability of a student has any influence on his/her performance

Mental ability has been found to influence performance of students in science (Biology) (Olagunju and Chukwuka, 2008; Raimi, 2003 and Salami, 2000). Carroll (1993) found out that the relationship between certain capabilities of mental abilities measured by academic performance of learners and intelligence test is significant. Furthermore, he found out that the performance needed on a number of mental ability tests such as, ability to apply knowledge to solution of problems, ability to manipulate abstract concepts and relationships and test of language competence are linked to performance in school learning. This suggests that there is a close relationship between ability and performance. Similarly, as cited by Adekunle (2005), Ajiboye (1996) asserted that knowing the intelligence level of learners will to a large extent determine how much the learner will achieve from a learning process or skill programme. Against this background, mental ability is included as a variable in this study.

Similarly, gender influence on academic achievement and science process skills acquisition has generated much concern among researchers. It has been a major debate among educators and researchers. Research studies have shown that gender can influence students' achievement in science (Nwagbo and Chukuelo, 2012; Okoye and Okechukwu, 2010; Olagunju and Chukwuka, 2008; Raimi, 2003 and Orji, 1998) and in practical skills acquisition (Bilesanmi-Awoderu 2002; Ige, 1998 and Duyilemi, 1997). There have been controversies on the influence of gender on students' achievements and practical/science process skills acquisition, with boys demonstrating higher ability skills in some tasks (Okeke, 2001; Toh, 1993 and Okebukola, 1992). Some researchers reported that girls perform better than boys in achievement and practical/science process skills acquisition (Bilesanmi- Awoderu, 2002; Duyilemi, 1997; Ikitde, 1994). However, researchers such as Okoye and Okechukwu, (2010); Oduwaiye (2009); Suits and Lagowski (1994) and Kanu (1993) contended that there is no gender related difference in students' achievement while Nwagbo and Chukuelu, (2012); Lock (1992) found no gender difference in acquisition of science process skills. They observed that gender did not affect the performance of students. The implication of these studies is that, findings from such studies have not come up with definite conclusions as to whether males or females are better achievers in performance and in the acquisition of science skills. Therefore, this lack of consensus on the influence of gender on learning outcomes makes the need for further investigation imperative.

1.2 Statement of the Problem

The prevailing poor achievement recorded by students every year in the Senior School Certificate Examination and National Examination Council in Biology suggests that the instructional strategies employed by teachers may be inappropriate and that students may not be well equipped with science process skills that can aid problem solving. This could result in producing fewer students who would go to higher institution to read Biology related courses. This could possibly lead to a reduction of manpower development in the areas of Medicine and Agriculture. Many earlier studies on problem solving instructional strategies aimed at addressing students' poor performance in Biology did not involve the students' production of instructional materials needed for practical activities. In order to ascertain the effects of problem-solving instructional strategy on students' performance, it is useful to conduct a study that involves students using instructional materials they produced themselves. Literature reviewed did not indicate that a study that employed two problem solving instructional strategies designed for students' individual work and for co-operative work in Biology Practical has been carried out in Nigeria. Besides, Bio Problem-Solving Instructional Strategy and Gayford Problem-Solving Heuristics have not been previously used in problem solving in Biology. This study therefore determined the effects of two problem-solving instructional strategies as it may affect students' achievement and science process skills in Biology Practical. It further determined the moderating effects of mental ability and gender on the learning outcomes.

1.3 Hypotheses

The following null hypotheses were tested at 0.05 level of significance stated to address the study.

1. HO_1: There is no significant main effect of treatment on students'
   (a) achievement in and
   (b) science process skills in Biology Practical
2. HO_2: There is no significant main effect of mental ability on students'
   (a) achievement in and

(b) science process skills in Biology Practical

3. HO_3: There is no significant main effect of gender on students'
   - (a) achievement in and
   - (b) science process skills in Biology Practical

4. HO_4: There is no significant interaction effect of treatment and mental ability on students'
   - (a) achievement in and
   - (b) science process skills in Biology Practical

5. HO_5: There is no significant interaction effect of treatment and gender on students'
   - (a) achievement in and
   - (b) science process skills in Biology Practical

6. HO_6: There is no significant interaction effect of mental ability and gender on students'
   - (a) achievement in and
   - (b) science process skills in Biology Practical

7. HO_7: There is no significant interaction effect of treatment, mental ability and gender on students'
   - (a) achievement in and
   - (b) science process skills in Biology Practical

1.4 Significance of the Study

The findings of this study could give teachers insight into approaches and strategies that would help them in lesson delivery and also make their teaching interesting, meaningful and stimulating. Teachers would also discover that problem solving instructional strategy could be attractive and effective not only for the motivational and realistic context it could provide but helpful to students of varying ability levels during problem solving task.

Science educators could use the instructional strategy in training pre-service teachers. Such pre-service teachers when trained would become competent and confident in performing their roles effectively as science teachers in the classroom and laboratory. Their use of the strategy would make the learner actively involved in learning by doing.

Thus, the learner will be able to be consistent with correct reasoning, ask appropriate questions and then solve problems that come their way in the environment.

The society will also benefit when students' academic achievements improve. This would increase the number of students that will enrol for the sciences in higher institution of learning. Consequently, this would translate to increased manpower in Biology related fields, leading to improved health, agriculture and other services.

Finally, the findings of the study would be of benefit to text-book writers because incorporating the strategy into their texts would increase the texts applicability for individuals, schools and interested groups.

1.5 Scope of the Study

The study was carried out in nine senior secondary schools drawn from Ibadan North, Akinyele and Ibadan North East Local Government Area in Oyo State, Nigeria. The participants of the study were Senior Secondary 2 Biology students. The study focused on the effects of two problem-solving instructional strategies (Bio Problem-Solving Instructional Strategy which involved the use of produced instructional materials by the students themselves and Gayford Problem-Solving Heuristics) on students' achievement and science process skills in Biology practical.

The effects of mental ability and gender on students' learning outcomes were also investigated.

1.6 Operational Definition of Terms

For the purpose of this study, the following terms were operationally defined as used in the study.

Problem Solving Model

This is a framework which shows the different stages a learner is expected to go through, such that, he/she progresses from a problem state to a solution state as the learner solves problem of an experimental type.

Problem Solving Instructional Strategy

This is a method of instruction in which students undergo training on how to solve problem by progressing in logical and stepwise approach from problem state to solution state.

Science Process Skills

These are the various skills the learners are to demonstrate as they carry out Biology practical investigations in the process of solving a defined problem. The skills include cognitive, manipulation, communication and observational skills.

Cognitive Skill

This measures how much the students have gained in the course of teaching the biological concepts in a practical test.

Manipulative Skill

This is a measure of how well the learners are able to set up the apparatus for experiments, handle them appropriately and use the instructional materials. Assessment on manipulative skill is based on direct observation of the learners when they are carrying out the practical work.

Communication Skill

This refers to the learner's ability to report accurately the experimental procedure and findings of practical work in a logical manner, either in drawings, oral or written form.

Observational Skill

This is concerned with the learner's ability to take note of all that takes place during practical work. It also measures how well they can recognise the features (details) that are present on the specimens or materials which they are working with.

Science Process Skills Test: This concerns the questions that were administered to the learners to measure the skills they acquired.

Modified Lecture Method

The instructional strategy that is commonly used in secondary schools where learners sit passively most of the time listening to teachers' lectures is modified with the inclusion of very little experimentation.

Instructional Resource Materials

These are the teaching aids or materials which the teacher uses in the classroom and in the laboratory to aid instruction and to promote the teaching process.

Mental Ability

This refers to assessment of learners' intelligence in terms of his/her ability to think and reason logically. Learners took a modified form of the ACER test and the scores were used to classify them into high, medium and low ability groups.

i. High mental ability group: Learners who scored 60% and above in the Australian Council for Educational Research (ACER) test.

ii. Medium mental ability group: Learners who scored 40% to 59% on the ACER test.

iii. Low mental ability group: Learners whose score fall below 40% on the Australian Council for Educational Research (ACER) test.

Achievement in Biology Practical: This is the learners' score in achievement test in Biology Practical (ATBP).

Learning Outcomes: These refer to the scores which learners obtained from the tests (Achievement Test in Biology Practical and Science Process Skills Test) through their exposure to the treatments, that is, problem solving instructional strategies and modified lecture method.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

The reviewed literatures were discussed under the following headings.

2.1 Theoretical Framework

2.2 Problem Solving

2.3 Problem Solving Models in Science

2.4 Problem Solving Models in Biology

2.5 Problem Solving as an Inquiry-based Instructional Strategy

2.6 Research Studies on Problem Solving in Biology and other Science Subjects

2.7 Practical Work, Achievement and Science Process Skills in Biology

2.8 Students' Involvement in the Production of Instructional Materials

2.9 Mental Ability, Achievement and Science Process Skills in Biology

2.10 Gender, Achievement and Science Process Skills

2.10.1 Gender inequality in Education

2.10.2 Studies on Gender, Achievement and Science Process Skills in Biology and other Science Subjects

2.11 Appraisal of the Literature

2.1 Theoretical Framework

The study owed its credence to the cognitive theories of leaning. Gagne and Briggs, (1978) saw the cognitive theories of learning as one which lays emphasis on complex, abstract, intellectual process such as thinking, problem solving and perceptions. The cognitive theorists lay emphasis on whole situations and on guided discovery methodology which emphasizes meaningfulness. They argued that when an organism has a whole perceptual view of problem situation, it will formulate guesses or hypotheses relevant to the solution of the problem. The emergence of the cognitive theory began with the efforts of the cognitive theorists who objected to the stimulus-response theories and saw problem solving as a complex mental activity which consisted of a number of actions and cognitive skills. Problem solving was found to consist of higher order thinking skills. In problem solving activities, principles, facts and theories which are previously learnt by the problem solver are combined with the view of finding a solution to problem. Therefore, the theories of Gagne and Piaget would provide the theoretical framework for this study.

2.1.1 Gagne's Theory of Hierarchical Task and Instructional Strategy

The Problem Solving Instructional Strategies used for this study are based on Gagne (1965) theory of hierarchical task. Gagne's 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 may take place. Gagne believes that meaningfulness of instructional materials can be achieved through movement from concrete materials to abstract, that is, learning should be sequentially structured. He advocated for the breaking of task into a sequence of steps which are arranged in a hierarchy. The theory of hierarchical learning is adapted 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.

Also, the problem solving instructional strategy drawn from Bio Problem Solving Model used for this study is based on Gagne's (1965) 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 Bio Problem Solving Model. An instructional strategy based on Gagne's theory begins with the teacher asking questions/ problem statements as in step 1 (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 is the step 2 (Gathering and processing information). The information relevant to the problem is first given during lecture before problems are provided. This information has to be recalled and combined before solution is arrived at. This is followed by task analysis which is steps 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).

Furthermore, this study emanates from the Conditions of Learning as propounded by Gagne (1962). The theory outlines nine instructional events by which a task can be learned by learners. This is similar to the steps in the problem solving models used for this study stating what students do at each step. Gagne's nine events includes, gaining attention, informing learners of specific objectives, stimulating recall of prerequisite learning, presenting new materials, presenting the stimulus, eliciting performance, providing feedback, assessing performance, and enhancing retention and transfer, (Gagne, Briggs and Wager, 1992). Gagne based his theory on skills and knowledge that are required by learners to be effective good problem solvers.

2.1.2 Piaget's Theory of Human Cognitive Development.

Piaget's theory of human cognitive development is also of relevance to the study as it provides explanation for the development of students' mental structures which are capable of influencing learning and understanding. Piaget stated that humans are able to respond to their environment by forming cognitive structures. This is possible because humans have inherited a method of intellectual functioning through two psychological mechanisms of adaptation and organisation. Mental adaptation is recognised by Piaget to take place through two complementary processes, assimilation and accommodation. Through these two processes [assimilation and accommodation], cognitive structures are formed which enables humans to engage in ever more complex thinking. Piaget's main interest was in the development of thinking but his work has great value for teachers, providing insight into comprehension, transfer and problem solving ability.

Piaget believed that cognitive 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 and handle hypothetical alternatives. Piaget's work on cognitive development 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 the possible combinations of the variables that can be employed in solving problems. This, the child can achieve by adopting this process which forms the building block of problem solving model.

1. organisation of data by concrete operational techniques
2. forming statements or propositions from results of concrete operational techniques
3. combining many propositions known as hypothesis and
4. evaluation

For teaching, this model of cognition suggests a graded problem solving approach. The learner is trained on how to solve problems by proceeding in a logical step by step sequence without jumping any step in a learning process. This means that whatever new concept that is presented to the learner, there must have been concepts that are prerequisites to that new knowledge in order for the learner to solve the existing problem. Piaget believed that the knowledge of a 'particular capability would be a prerequisite for a much higher capability' and that learning is through activity and experience. To him, new experience must be meaningfully related to background experience and the new ideas and activity must be presented at the level and rate consistent with the stage of development of the child. Also, 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 student's problem solving difficulties. Therefore, the knowledge of Piaget's theory of cognitive development will tremendously assist the researcher in the course of this study as Piaget's analysis of cognitive development can help teachers match curriculum with the abilities of children.

2.2 Problem Solving in Education

Problem Solving is a basic skill which is very vital to today's learners. More emphasis is placed today on the globalization of the market place, democratization of work place, new technologies, and multiple roles on most jobs. Therefore, educators and trainers are concerned with the revision of curricula in different subject domain to include integrated learning environment which encourage learners to use higher order thinking skills especially problem solving skills. Education has come under serious criticism from many sectors for its failure to help students develop higher order thinking skills. A number of people have argued that the separation of content from application has adversely affected our educational system (Hiebert, 1996). The learners are usually exposed to facts and rote methods of learning with little or no links to the context and application of learned facts. Problem Solving has been regarded as the linking ties between context and application in a learning environment for the development of basic skills and their uses in various dimensions (Kirkley, 2003). The need for learners to become successful problem solvers is gaining ground among educationist confirming the assertion made by Gagne, (1982) who believed that "the central point of education is to teach people to think, to use their rational powers to become better problem solvers'. Similar to Gagne's belief there is a general consensus among most psychologists and educators that problem solving is the most important learning outcome for life because almost everyone in their everyday and professional lives are regularly involved in solving problems. Great emphasis is being placed today on learners to acquire higher order thinking skills and basic literacy skills which are in high demands in various workplaces. For learners to meet the workplace needs, U.S Department of Labour's Secretary's Commission on Achieving Necessary Skills (SCANS) in 1991 recommended that "teaching should be offered in context, and students should learn content while solving realistic problems.

The need to get students involved in problem solving has been greatly emphasized by science educators. Ige (2003) gave two reasons why students should engage in problem solving. These are:

i) To help students acquire functional concepts, principles, ideas and so on, relevant to a specified content domain (specified in scheme of work or syllabus)

ii) To provide experiences for students that will help them develop strategies for facing real life issues out of school

Problem Solving means different things to many people. 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 (Kirkley, 2003). The problems generated usually have correct answers which are based on the logical solution that has only one right answer (convergent reasoning). However, under the influence of cognitive learning theories, problem solving became a complex mental activity which consisted of a number of actions and cognitive skills. Problem solving was found to consist of higher order thinking skills, for example, "visualization, association, manipulation, abstraction, reasoning, comprehension, analysis, synthesis, generalization each needing to be 'managed' and 'coordinated' " Garofalo and Lester, (1985).

The key to successful problem solving lies on the development of a mental model with the right kind of structure for solving a particular class of problem. Therefore, helping learners build their mental models successfully as they set out to solve a problem must be given serious attention to by teachers.

2.3 Problem Solving Models in Science

A number of problem solving models have emerged in the last three and half decades in science to address the problem solving difficulties encountered by students. These problem solving models were developed to help improve the problem solving behaviour of students particularly in physics, chemistry and mathematics with few in biology. In this section, problem-solving models in other subject areas will first be discussed which will be followed by problem solving models in biology.

2.3.1 Ashmore, Cassey and Fraser's Problem Solving Model

Ashmore, Cassey and Fraser (1979) developed a four stage model for solving both numerical and non-numerical chemical problems. It is a model that has been used extensively by chemistry educators in addressing the problem solving difficulties of students in chemistry. For illustrative purposes, the following quantitative problem was employed:

> A moth is found to have a respiratory rate of $50cm^3$ oxygen/hour. If sugar is the source of energy; what is the maximum amount of sugar the moth must gather from flower in an hour?

This illustrative question posited by these research workers does not suggest the application of an experimental design neither does it require experimentation or analysis in solving the problem to get an answer or to arrive at a solution. Therefore, employing this model as shown in Figure 1 for enhancing students' science process skills in biology is not likely to be very effective though stage 2 of the model which requires students drawing out necessary information from knowledge gained from their past experiences can be applicable in investigative context. Students need past experiences and knowledge of the subject matter to be productive inquirers (Jonassen, 2000). Adesoji, (1998); Anchor (1995) reported that Ashmore, Fraser and Cassey's problem solving model is suitable for solving problems and for identifying students areas of difficulties in science. This presupposes the impracticability of the model for practical purposes as is required for this study.

STAGES	Comments
1 Define the problem	A problem that is clearly defined is halfway solved. At this stage, the objectives of the problem should be clearly understood by the problem solver
2 Select appropriate information	This stage involves thinking about the problem statement and sorting out the relevant information from students' repertoire of knowledge and from the problem statement.
3 Combine separate piece of information	This stage involves the problem solvers' exploration of possible solution through examination of alternatives, brainstorming and putting the pieces of information together.
4 Evaluate	At this stage, the problem solver assesses and evaluates the consequences of the various activities carried out and ensures that the solution to the problem is correct.

Figure 2.1: Ashmore, Cassey and Fraser's Problem Solving Model

However, the stages outlined in the model can guide the researcher in modifying the existing problem solving models that is adequate for this study.

2.3.2 The Ideal Problem-Solving Model (Bransford and Stein, 1984)

This model became operational as a result of the need to develop a general problem solving model to explain the processes involved in problem solving. The Ideal Problem Solver is a model of information processing and solution construction. The origin of the model is based on the assumption that by learning abstract (de -contextualized) problem solving skills, one could transfer these skills to any situation (context).

The Bransford and Stein Ideal Model is a five stage model

a. Identifying problem
b. Defining the problem through thinking about it and sorting out the relevant information
c. Exploring possible strategies
d. Acting on those strategies
e. Looking back and evaluating

This model of problem solving is still employed with many problem solving courses such as stand-alone courses found in academic and corporate training settings. These stand-alone courses teach problem solving as a "content-free" thinking skill. The Ideal Problem Solving Model is descriptively useful and it regards or treats all problems the same.

Jonassen (2000) stated that problem solving is not a uniform activity because problems are varied in content, form or process and as such, no generalized problem solving model (such as proposed by Bransford and Stein) can satisfactorily handle the problem solving difficulties in all subjects. However, the model still holds credence to a large extent to this study as the stages in the model can be adapted in the development of the model proposed for the study.

2.3.3 Problem Solving Based Model by Pizzini, Shephardson and Abel (1989)

The problem solving based model developed by Pizzini, Shephardson and Abel (1989) consists of a four step cyclical model which involves searching, solving, creating and sharing and allows for re-entry into various stages of the model as students engage in problem solving. The model is generally referred to as Search, Solve, Create, Share (SSCS) problem-based instructional method. .The model consists of the following phases

1. **Search phase of the SSCS Model**

Students read articles from science newspapers or magazines and materials prepared by the researcher and the classroom teacher. Thereafter, students identify problems of researchable questions.

2. **Solve phase of the SSCS Model**

In this phase, students are made to individually prepare and set in motion their plans by analyzing and investigating the information/questions gathered from their search.

3. **Create phase of the SSCS Model**

Students generate solutions by engaging in group discussion and communicating with one another. The different groups are then required to make meaningful contribution during the general discussion in order to arrive at a consensus solution.

4. **Share phase of the SSCS Model**

Students within a group reflect on, evaluate solutions and answers, and at times present ideas or answers to the class in the modified share phase. The following important characteristics are drawn from the application of the model

i) Students develop more skills as they use problem solving strategies

ii) They become aware of their own ideas and ideas of others, including conflicting opinions among class members.

This model will serve better in cooperative or group work rather than individual work. However, it is very likely that the phases in the model when adapted for this study can enhance students' practical skills.

2.3.4 Mettes, Pilot and Rooserick Problem Solving Model

Mettes, Pilot and Rooserick (1981) developed a systematic approach to solving chemical problems which evolved from Gal'perin learning theory of stage by stage formation of Mental Action. This model can also be applied to solving problems in areas of science and technology. Two distinct parts make up the Mettes et al model. They are:

i) Part 1, Programme of Actions and Methods (PAM)

ii) Part 2, the operational phase which is concerned with the heuristics involved in problem solving.

In a systematic way, PAM brings out the actions and methods that should be followed in solving problems. Mettes et al believed that the success of applying their model in solving problems in chemistry would greatly depend on:

i) An absolute understanding of the problem context

ii) Providing explanatory notes on each stage

iii) The correct mastery of each stage

iv) A general method of thinking

The model consists of four steps which are listed below and represented in Figure 3.

i) Analysis of the problem

ii) Planning the problem solving process

iii) The execution of routine operations

iv) Checking the answer/interpretation of the results

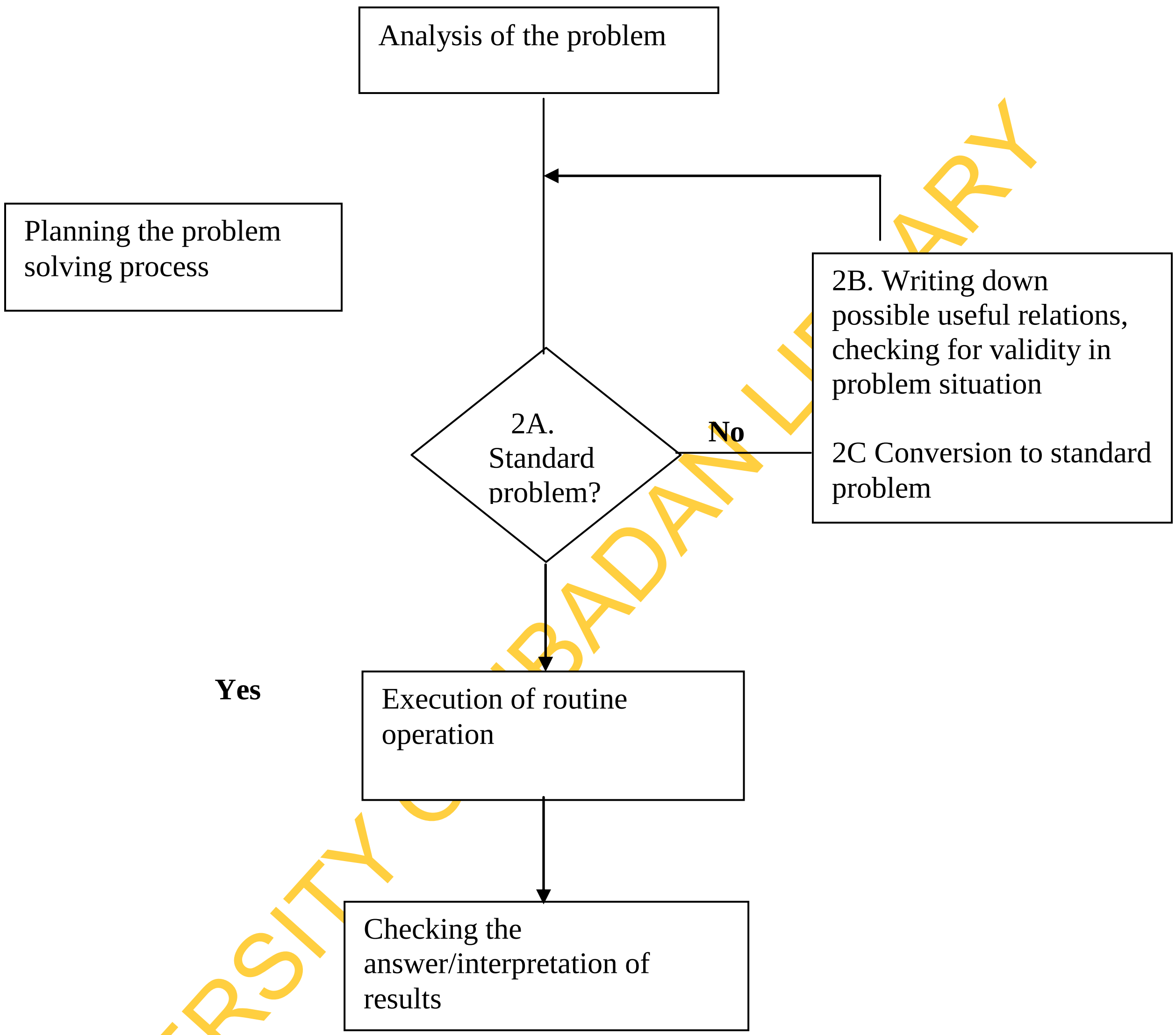


Figure: 2.2. Mettes et al (1981) Programme of Actions Methods (PAM) for Systematic Problem Solving Model

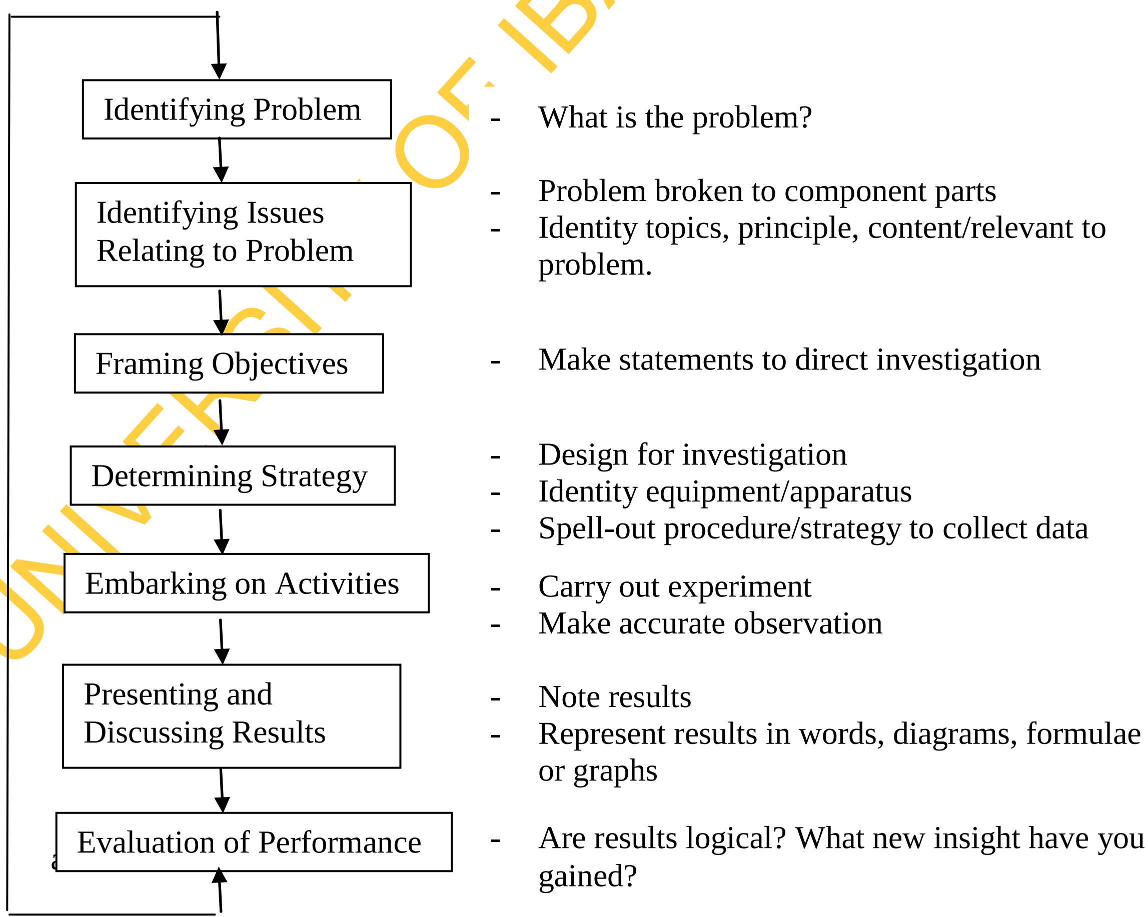
Mettes et al employed this model in dealing with difficulties encountered by students in solving quantitative problems in chemistry. The students were exposed to problems in their first year course in general chemistry and were expected to solve problems while thinking aloud. Students' answers to the test and examinations administered to them afterwards were analysed and used as evaluation guides to analyze their 'thinking aloud' problem solving. The authors discovered that the students were unable to apply the model in solving problems successfully because:

- Students do not know how to begin the problem solving process
- They could finish but came up with a solution that is incorrect or that is not a solution to the original problem

PAM is specifically designed to address numerical problems in chemistry and thus it is not very suitable for practical purposes particularly in Biology. However, the heuristics involved and the various phases particularly phase 2 (2A-2C) will be very helpful when developing a practical problem solving model in Biology like the one proposed for this study.

2.3.5 Inquiry-Based Framework for Practical Problem Solving

West (1992) developed a problem solving model which was meant to help teachers and learners solve different types of problems, train students in problem solving and address difficulties students encountered in problem solving. Ige, (2003) produced a modified version of West problem solving model, designed for use in science practical classes. This model is known as Inquiry-based Framework for practical problem solving which comprises of seven steps namely:



This model in clear terms shows the various steps students can follow in a practical class to solve an experimental problem. Students' ability to apply this model to solve problems would demand from them good theoretical background based on knowledge and understanding of facts, principles, theories and strategies necessary to arrive at the solution to the problem. The teacher will however, at each stage help students draw on their knowledge by either asking them relevant questions or making statements to direct their thinking as they carry out the experiments under investigation. This model has been designed to solve practical problems in Science in which students are exposed to activities/learning tasks that can assist them acquire strategies for the identification of learning issues, retrieval of information from their cognitive domain and the application of essential resources to solve problems. The seven-step model is for solving students' practical problems in the sciences generally. It is on the basis of this that the model will be of much assistance during the course of developing the model for this study.

2.4 Problem Solving Models in Biology

Ability of learners to solve problems has become one of the major goals of science education. Literature on problem solving as it relates to science education abounds. These literatures have paid specific attention to the nature of problems, the significance of problem solving in students' academic achievement and the various problems students are likely to encounter in school and out of school. Most of these researchers on problem solving are concentrated in the physical sciences and mathematics. However, little literature relating to problem solving in Biology is available (Ikitde, 2004). Some of such reviews will be considered in this study.

2.4.1 Gayford's Problem Solving Heuristics

Gayford developed a 9-step strategy for solving experimental biological problems in a logical and step-wise approach. At each step, question actions which the problem solver is expected to go through are indicated below:

1) What question, if any, do you want to ask:

> Remember that (teacher) is not going to tell you how to solve the problem and part of the teacher's job is to decide how much help you needed where marking your work. However, there are some things that you may want to know before you get on. Perhaps would help you if you wrote down the question that you want to ask. Discuss the question with your partners before you try this.

2) Now, try to write down exactly what you think the problem is or what you are trying to do.
3) Think about how someone else is likely to judge how successful you have been in solving the problem. Write this down.
4) Is there anything that you have learned in school or anywhere else which may help you with this problem?
5) Think of as many different ways of tackling this problem as you can.
   It is important that you discuss your idea with our group.
6) Select the best method that you think will work in the time that you have available and with the materials you have.
7) Once you have begun, decide whether you think that the method that you have chosen will work.
   Do you need to make any minor or major changes? If so, what are they?
8) Can you identify any further problem that you need to investigate before you can really solve this one?
9) How successful do you think that you have been?
   Why? Can you measure your success?

This approach has many steps; it is wordy and cumbersome to be used in the classrooms, laboratory or on the field. Assessing individual student's participation in learning using the numerous steps can be difficult. However, this approach can serve for group or co-operative activities.

2.4.2 Henderson and Lally Problem Solving Chain

Henderson and Lally's intention of developing the problem solving chain was based on their attempt to make teachers put aside the traditional methods/teacher-centred instructional strategies they were accustomed to and to begin to employ problem solving approaches. They believed that such approaches were capable of helping students develop independent mind that would prepare them to identify, handle and solve problems they encounter daily in life and the society in general. They came up with group of statements.

1. Students should feel that they 'own' the problem.

> For this to happen, they must have sufficient freedom to determine for themselves what it is they are investigating and how they should go about it. Ownership of the problem is essential if they are to be stimulated to attempt to find a solution.

2. Cooperative group work provides an appropriate framework for problem solving, allowing students to develop skills of communication, listening, organizing and decision making.
3. Appropriate problems are those which can be solved in different ways.

   Students should feel that there is a real uncertainty in the outcome of results and should not think that the teacher knows the *right* answers. Students must understand that *procedural excellence* is what matters and not the answer'. If your teacher does not follow the right steps, he cannot have the answer accurate or reliable.
4. Pupils need to learn that experiments do not always have *right* answers; and you must realize that problems would only have meaning to the students if they are set in a social context.

This approach can be used in teaching the theoretical aspect of the content and it is also suitable for laboratory work. However, this approach like the Gayford's problem solving heuristics is most suitable for group/cooperative work than for individual work. The model is represented in figure 2.3.

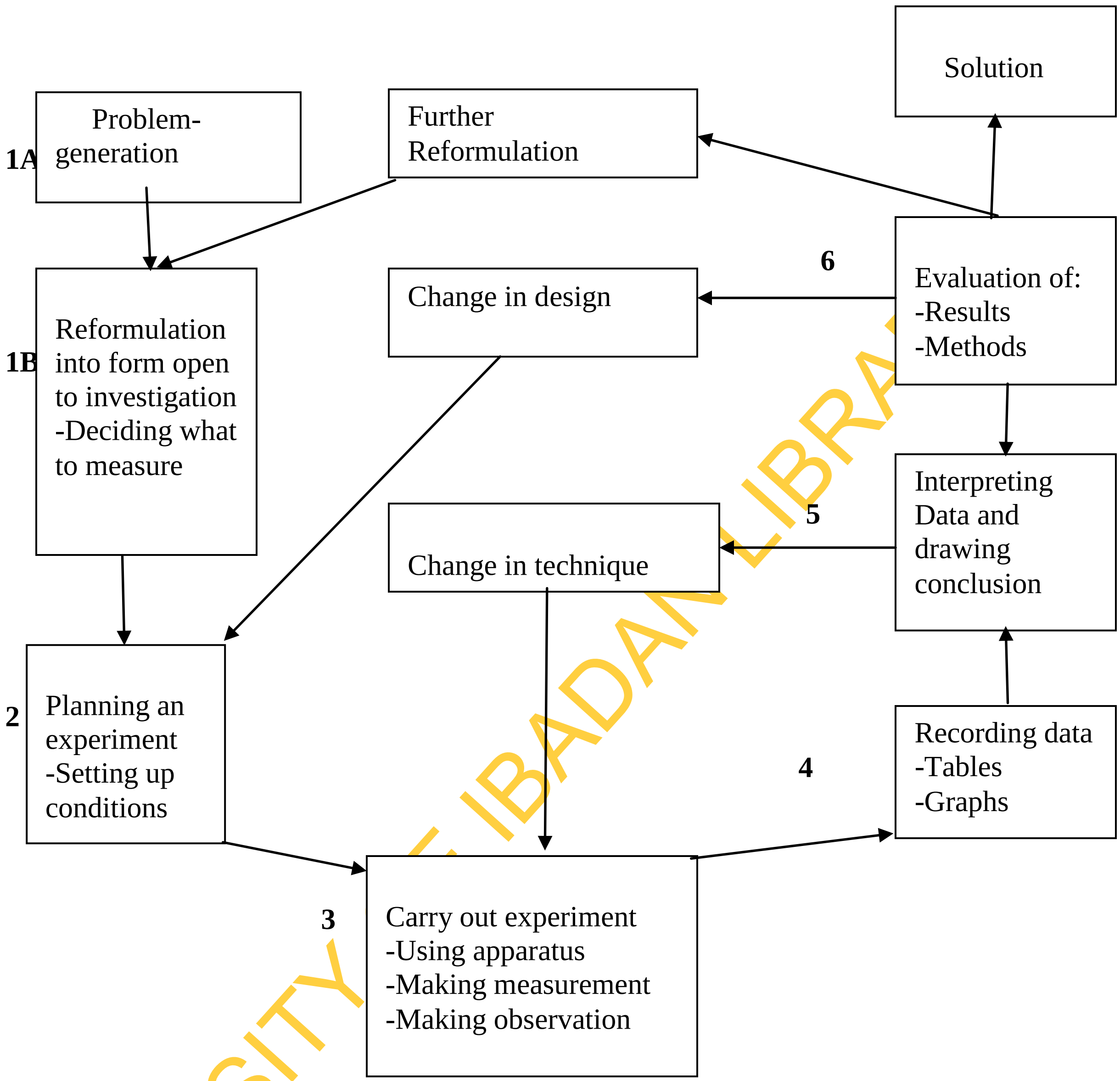


Figure 2.3: Henderson and Lally Problem Solving Chain

2.4.3 Researcher's Experimental Problem Solving Model (REPSOM)

Ikitde (1994) developed a 5-step problem-solving model designed to foster experimental proficiency of students in biology. This model is made up of two parts. The first part consists of five procedural stages, while the part II clearly indicates what the teacher is expected to do at each stage (the actions).

The Five Stages are:

- A and B: Problem reception and selection apparatus
- A and B: Recalling theory and making tables
- Experimentation, Observation and recording data
- Analysis of results
- Evaluation of solution, consolidating knowledge gains and change in technique

This model specifies what the students are expected to do at each step of the process, the teacher being the facilitator. The viability of the model lies in the fact the stages are cyclical, sequential and hierarchical and the extent of obtaining success in one stage determines the successes to be achieved in the preceding steps. Thus, adapting this model will in a long way guide the researcher in the development of a problem solving model that can address students' underachievement in Biology practical examinations especially in the aspects of mammalian skeletal system and other closely related areas in biology.

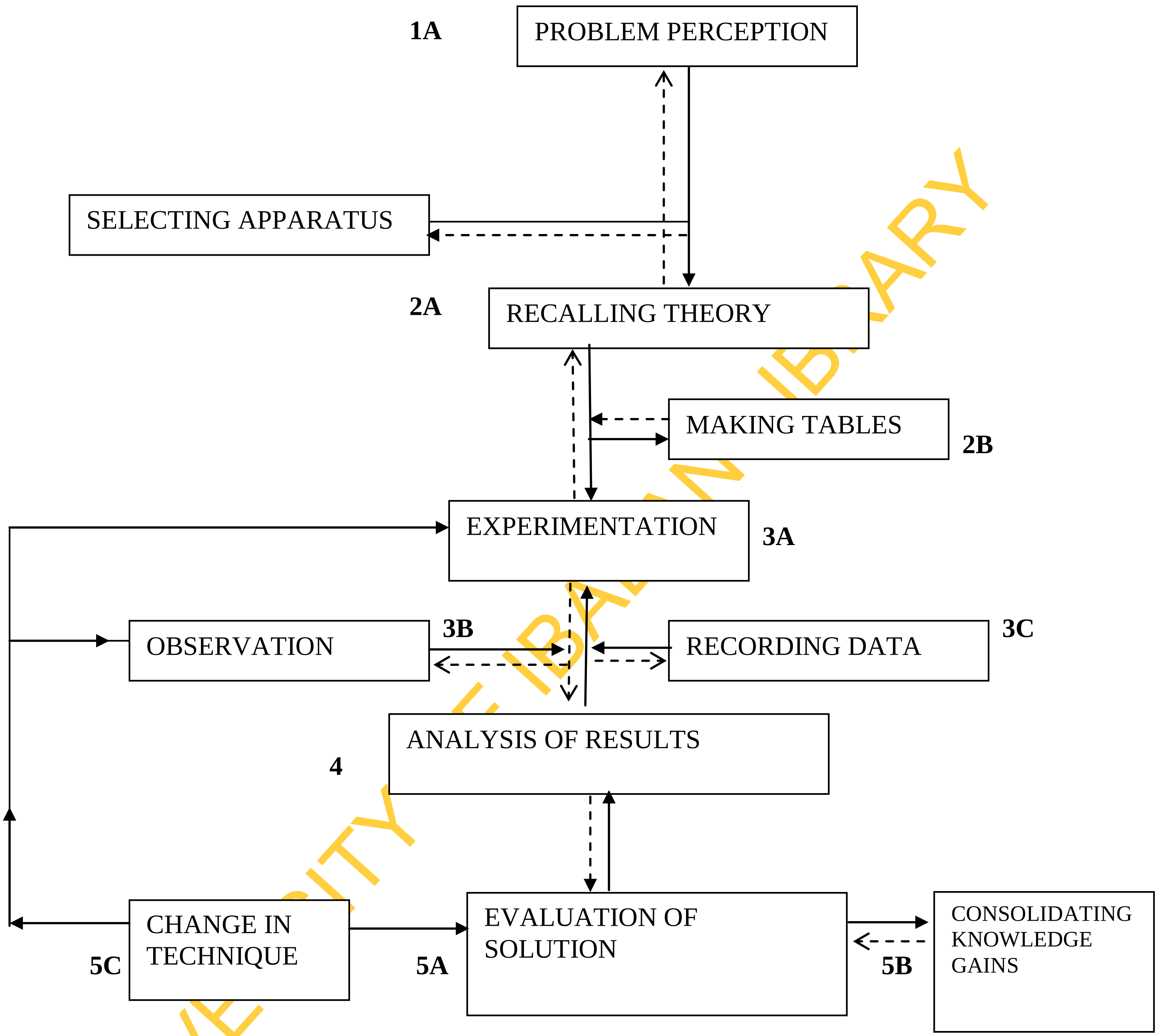


Figure 2.4: Researcher's Experimental Problem Solving Model

2.4.4 Slack and Steward Problem Solving Heuristics

Slack and Steward (1989) worried about students problem solving difficulties in genetics, proposed a content independent heuristics for solving problems in genetics. They came up with the following steps:

i) Setting sub-goals
ii) Working backward
iii) Working forward
iv) Re- describing data
v) Generating hypothesis from re-description
vi) Considering alternative hypothesis
vii) Checking results
viii) Consolidating knowledge gains

The approach is very useful as students can engage in independent activities without a science teacher and still solve the problem. The inclusion of the 8th step gives the students the opportunity to assess what they have achieved from solving the problem and to seek out ways of applying the knowledge gained to new situations. However, this model is content based rather than for practical skills acquisition.

There is a general pattern in the models reviewed so far. Students are required to pass through various steps or stages as suggested in these models to progress from the stage of the identification of the problem to the stage of the solution of the problem. However, these models are varied in the heuristics involved and in their scope of applicability. Furthermore, most of these models are developed in the field of chemistry and physics. Besides, the present problem solving models in Biology may not likely be completely relevant in dealing with most aspects of biological concepts particularly in the aspects of tissues and supporting systems in plants and animals which the researcher intends to address in this study. Jonassen (2000) stated that the problems or difficulties of students to be addressed must guide the development or construction of problem solving model.

Having identified the major components of problem solving models in the field of science, especially in Biology, the researcher came up with a problem solving model based on Researcher's Experimental Problem Solving Model (1994) which is a step by step procedural guide to device a model known as Bio Problem Solving Model (BioPSOM) to be used by teachers and learners to solve practical problems and for the development of science process skills.

2.4.5 Bio Problem-Solving Model

The problems or difficulties of students to be addressed should guide the development or construction of a problem solving model (Jonassen, 2000). Though the essential components of the existing problem solving models such as Gayford Problem-Solving Heuristic, West Problem Solving Model, Researcher's Experimental Problem Solving Model (REPSOM) can bring about meaningful learning, changes in curriculum, new technologies, students professional development and most importantly students' persistent high rate of failure due to their inability to develop appropriate science process skills in Biology for improved performance point to the need to update instructional models. This is in line with the report of MUSE (2000) (Modeling for Understanding in Science Education), which says that mental models should continuously undergo revision in order to use them to probe new phenomena and collect additional data. The Bio Problem Solving Model (BioPSOM) is a modified model with five steps based on Researcher's Experimental Problem Solving Model (1994) as shown in figure 3.1 (appendix I).

Bio Problem Solving Model is a five-step model consisting of the following stages (see appendix 1). The steps are:

1. Recognition of problem
    a. problem examination
    b. restating problem
2. Gathering and processing information
3. Experimentation
    a. Instructional material production
    b. Engaging in practical work
    c. Observation
4. Analysis of Results (Report, draw and discuss results)
5. Evaluation

   Recheck Result

The Bio Problem Solving Model (BioPSOM) identifies the following basic sequence of the cognitive activities in problem solving.

1. **Recognition of Problem**

(a) **Problem examination**

The preliminary responsibility of a problem solver is to identify and acknowledge that there is a problem or a difficulty that requires attention. This is followed by the determination and several attempts to fully understand what the problem demands.

(b) **Problem re-statement**

The problem can be re -stated clearly and objectively by the teacher when the students fail to understand the problem statement. Questions as stated below can be asked:

(i) Can this problem be stated in some other ways?

(ii) If yes, how else can it be stated?

2. Gathering and Processing Information

Students' ability to analyse questions, take note and recall relevant information that can be helpful in problem solving is an essential step in the problem solving process. Roberts and Gott, (2003) considered investigations to be dependent on a body of knowledge. They also reiterated that in problem solving, scientific investigation does not only require basic skills but also requires a procedural understanding of the ideas or concepts that corroborate evidence. Roberts and Gott (2003) in their own words stated that:

> Problem solving in science is seen to require the understanding of sets of specific ideas or concepts: a substantive understanding and a procedural understanding. Thus, the mental processing that is required when solving problems in a Biology context involves thinking about the substantive ideas of Biology and specific ideas required to collect valid and reliable evidence (p.116).

In the light of this assertion, solving an experimental problem in Biology rests partially on the extent of theoretical background knowledge in form of theories, facts and principles relevant to the problem to be solved that a learner has. Consequently, at this stage, the problem solver should have recourse to his prior knowledge of the theoretical background of the problem. It is on the basis of the relevant background knowledge and requisite knowledge that the problem solver will be able to carry out the investigative process. Also in a situation, where students have no background knowledge of a topic, teachers must provide information and background that motivate students.

At this stage the problem solver will carry out these exercises prior to investigation.

(a) Analyse the problem, read about it, break the problem statement into component parts taking note of the relevant information

(b) Write down in your notebook general principle or theory and facts that can help you in the problem solving process.

(c) Recognize limitations of prior knowledge or experience.

(d) Identify a most suitable strategy that you can use to solve the problem.

(e) Identify the difficulties that you are likely to encounter in the problem solving process and set up strategies to deal with them.

(f) Ensure you have the recommended WAEC materials for biological drawings – HB pencil, eraser, ruler and so on.

3. Experimentation

This is the problem solving process which can be referred to as the action – stage. At this stage, the learner engages in thought-provoking problem-solving exercises intended to enhance such laboratory skills as cognitive, manipulative, observation and communication skills. This stage is further divided into three sub-stages which are intermixed.

Instructional Material Production

Production of instructional materials can be carried out by the students. Teaching becomes more effective when teachers guide their students to produce instructional materials. In the course of producing instructional materials under the guidance of their teachers, the students can come up with their own ideas, perceptions and what is needed for the experiment. In the process, the students are able to explore, test and identify the relationship between structures and functions of parts of the plants and animals. Besides, the students are able to understand biological concepts which help them to reason out solution rather than depend on rote memory. During this stage, the problem solver would prepare or produce the materials that will be used for the laboratory activity under the supervision of the teacher.

3. A. Engaging in Practical Work

This sub-stage is the "hub" of the problem solving process/stage. The problem solver sets up the experiment using the instructional materials produced where appropriate. The problem solver then manipulates the materials for the experiment while demonstrating various practical skills as the problem solver tries to solve the problem.

3. B. Observation

This sub-stage involves the problem solver taking note of all experimental happenings as well as taking note of every detail present in a given specimen (an instructional material). Herderson and Lally, (1988) expressed that making systematic observation is the building block of a basic training in experimental Biology. In short, accuracy in observation is very essential in Biology practical. Teachers should endeavour to monitor their students as they engage in practical work before the students represent their observations in drawings or in their recording sheets.

4. Analysis of Results (Report, Draw and Discuss Results)

At this stage students are to report accurately all observed facts in diagrammatic form with appropriate magnification showing parts proportionate to each other. The drawings must be neatly labelled using horizontal guidelines. Each drawing must have a title.

5A. Evaluation

At the end of the practical activities, the problem solver would review the report or results and ascertain its logicality. The problem solver should be able to detect any discrepancies from already established theories and principles and thus state if such results obtained can lead to new knowledge.

5B Recheck Result

When results do not conform to existing body of knowledge, sources of error can be traced to appropriate stages of the model. This continues until a most probable solution is obtained. The mistakes students make can be used to make necessary corrections.

2.5 Problem Solving as an Inquiry-based Instructional Strategy

Problem solving as a method of inquiry can be used to teach problem solving skills and to engage students in dealing with and solving of real problems. Problem solving in the context of inquiry engages students in problems that are real and relevant to them. They can be problems that the teacher has presented to the students for investigation or problems generated by the students themselves. A good number of science educators (Akinbolola and Afolabi, 2010; Nwagbo, 2008; Ibe and Nwosu, 2003; Abraham, 1997; Hofstein and Lunetta, 1982; Johnson and Lawson, 1998; Musheno and Lawson, 1999) have indicated that the inquiry-based instructional approach is the most appropriate instructional method for teaching science. This approach to teaching emphasizes the learner centred instructional technique. Von Secker and Lissitz (1999) held up the view that the student-centred approach to learning "engages student socially in interactive scientific inquiry and facilitate lifelong learning". Besides, science educators believe that the practice of inquiry is fundamental to the student-centred approach to learning science. The National Research Council (1996) states that, "Inquiry into authentic questions generated from student experiences is the central strategy for science teaching". The National Science Education Standards (1996) describe inquiry as:

> a multifaceted activity that involves making observations; posing questions, examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in the light of experimental evidence ;using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions, and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. p.23.

Also, inquiry has been defined as "the dynamic process of being open to wonder and puzzlements and coming to know and understand the world" (Galileo Educational Network, 2004). Hinrichsen, Jarrett and Peixollo (1999) in their work, clearly stated the essential traits of inquiry. These they described as:

i) Connecting past know ledge and experiences with the problem at hand

ii) Designing procedures to find answer to the problems.

iii) Investigating phenomena through data collection

iv) Constructing meaning through the use of logic and evidence. Other traits which they considered as less assessable include: collaboration, responding to criticism and practicing habits of minds, such as honesty, and integrity in reporting findings. Subsequently, the following traits have been highlighted in the laboratory science models and were considered as essential and assessable traits of inquiry:

i) Connecting personal understandings with those of sound science;
ii) Designing experiments;
iii) Investigating phenomena;
iv) Constructing meaning from data and observations.

Inquiry-based learning is seen as a process whereby students are involved in their learning, generate questions, investigate extensively and then build new understandings, meanings and knowledge (Alberta Learning, 2004). The students use the new knowledge which they acquire to answer questions, solve problems or to make the problem statement clearer. Inquiry based learning gives the students the opportunities to:

i) Develop skills they will need all their lives;
ii) Learn to cope with problems that may not have clear solutions;
iii) Deal with changes and challenges to understandings;
iv) Shape their search for solutions, now and in the future.

Moreover, Drayton and Falk (2001) gave the characteristics of the classroom where teachers apply the inquiry based learning. These are:

i) Inquiry is in the form of authentic (real life) problems within the context of the curriculum and/or community
ii) The inquiry capitalizes on students curiosity
iii) Data and information are actively used, interpreted, refined and digested ;
iv) Teacher, students and teacher-librarians collaborate;
v) Community and Society are connected with the inquiry;
vi) The teacher models the behaviours of inquirer;
vii) The teacher uses the language of inquiry on an ongoing basis;
viii) Students take ownership of their learning;

ix) The teacher facilitates the process of gathering and presenting information;

x) The teacher and students use technology to advance inquiry;

xi) The teacher embraces inquiry as both content and pedagogy;

xii) The teacher and students interact more frequently and more actively in an identifiable time for inquiry based learning

Education standard (1996) called for "a pedagogical shift from a teacher-centred to a student-centred instructional paradigm". It was recommended that students must put aside the simple memorization of facts and regurgitation of what they have learned and begin to build up new meanings and a better understanding of facts through identification and its application to the solution of specific problems (Owens, Hester and Teale, 2002). Supporting this recommendation, Gerber, Marek and Cavallo (1997), concluded by saying:

> In (science) classes taught by inquiry, individuals are actively engaged with others in attempting to understand and interpret phenomena for themselves; and social interaction in groups is seen to provide the stimulus of differing perspectives on which individuals can reflect p.3.

Research on Inquiry based learning shows that students improve in their academic performance considerably, as they engage in inquiry in their classrooms (GLEF, 2001). Several research studies are available to support this claim.

Johnson and Lawson (1998) investigated the relative effects of reasoning ability and prior knowledge on biology achievement in expository and inquiry class. In their study, one-half of the students received instruction through teacher-directed approach while one-half were taught through an inquiry based approach. The results showed that students who received biology instruction through the inquiry approach demonstrated greater improvement in reasoning ability than the students who were taught through the expository method. Again, the inquiry students demonstrated a higher overall performance in biology achievement. In conclusion, Johnson and Lawson emphasized that "nothing of importance seems to be lost by switching to inquiry instruction, and much seems to be gained".

Haury (1993) agreed with the assertion that inquiry is linked with hands-on learning, experiential or activity- based instruction, development of science process skills and problem solving, and that, inquiry is not synonymous with these concepts but interrelated. Doolittle and Camp, (2003) stated that, "In the broad content of general education, inquiry or problem-based learning (PBL) are more generally used terminologies than problem solving, but the fundamental aspects of problem-solving and inquiry or PBL are analogous". A cursory look at what systematic inquiry entails, particularly at the first step or "exploration" phase of learning is the identification of a "problem" followed by the process of seeking solution to the problem. These are basically the elements of problem solving approach.

Problem solving is an important instructional strategy for constructing and negotiating meaning (Ebenezer and Connor, 1998). It is a teaching strategy which has to do with methods and learning skills that have been found by science educators to be very important when learning science through investigative technique. As far back as six decades ago, Lacelot (1944) spoke of the effectiveness of the problem solving method in his own words, "In general, those teachers who keep their students thinking teach their subjects by means of problems…" (p.144). He went on further with the assertion that, all subjects can be effectively taught using well structured and articulated problems. Krebs (1967) strongly recommended the problem solving method as an instructional strategy because of its practicability and usefulness in promoting meaningful learning. He had this to say, "One of the values inherent in a problem-solving approach in teaching is that it is not a process which is strange or unused by people in general". In essence, people are always engaged in solving problems, problems of varying degrees.

The problem solving strategy has been found to be an important pedagogical approach that has been used by many teachers to facilitate and extend student learning. To this end, Akubuilo (2004) stated that "problem solving instructional strategies, which result in improved cognitive development, acquisition of skills and retention of subject matter learnt could lead to improved attitude towards solving life problems". Earlier, Dyer and Osborne (1996) had stated that "the problem solving approach is more effective than the subject matter approach in increasing the problem solving ability of students", and that this "increase transcends learning styles". Warmbrod, (1969) identified the problem solving approach as "instruction (that) is student-centred rather than subject centred; (in which) instruction aims at the development of and change in behaviour of individuals". In addition, he saw the problem solving approach as "teaching and learning as a cooperative venture between the students and teacher rather than a completely teacher-dominated process". Further, Chang, 1999, reported that, "a model of problem solving based instruction significantly increases students' science achievement and notably modifies alternative frameworks of students. This approach with an emphasis on the application of science concepts develops students' higher, mental skills and facilitates students' learning".

2.6 Research Studies on Problem Solving in Biology and other Science Subjects

Research on problem solving experienced a precedented increase from the 1960s. At that time, researches on problem solving was concerned with the manner in which people solved puzzles and games, for example playing of chess as well as problems involved in logic and crytarithmic. This marked the beginning of researches in problem solving. In the early 1970's attention of researchers moved to the use of think-aloud protocol in research studies. Researchers made use of tape-recorded think-aloud protocol as well as interviews to gather data to help them solve problems (Reif, Larkin and Bracekett, (1976); Bhaskar and Simon, 1977). Changes in research on problem solving continued and became more dynamic. This became the driving force to the researches in the 1980's where research on problem solving gained grounds in the domains of information processing theory involving information retrieval from memory with the proper application of such information to solving problems (Richardson, 1981; Mettes, Pilot and Ressink, 1981). In the early 1990's researchers devoted their work to identifying the differences between the problem solving ability of expert and novice problem solvers (Mayer, 1992).

Currently, literature on problem solving is dominated by research work on problem representation, mental model construction and improving cognitive skills of students who are involved in problem solving. Emphasis on research studies are on the internal cognitive process that results in steps involved in problem solving. Several research works in Biology, physics, chemistry, mathematics and earth science have been carried out on the problem solving ability of students. Those relevant to this study have been identified and reviewed.

Ajueshi (1990) adopted Bloom's Learning of Mastery (LFM) model and the Ashmore et al problem solving model to address students' problem solving skills in Chemistry. A total of 119 form 4 students were involved in the study. The results revealed that mastery of both problem solving heuristics and chemical content had a better facilitated effect in promoting problem solving skills than mastery of either problem solving heuristics or chemical content.

Adesoji, (1991) carried out a study on the comparative analysis of problem solving and self- learning techniques in the teaching of electrolysis. The study involved three hundred and sixty senior secondary class two chemistry students. The participants of different ability levels (high, medium and low) were assigned to the treatment groups, that is, Problem-solving Technique, Self-learning Technique and the Lecture Method. Seven hypotheses were raised and tested using Analysis of Variance, Analysis of Covariance and Scheffe test. The results of the analysis revealed that the students exposed to problem solving strategy performed better than those taught with the self-learning approach and the lecture method. The findings proved that the systematic approach to problem solving enables students to progress from one stage of the problem solving to the other.

Ikitde, (1994) carried out a study involving sample of 210 senior secondary school students (121 boys and 89 girls) of Biology drawn from three secondary schools in three senatorial district of Akwa Ibom state to investigate the comparative effectiveness of two problem solving approaches in fostering experimental proficiency of students in Biology. The experimental skills he examined were cognitive, manipulate, observational, communicative, and independent and work ethic skills, while the intervening variables of sex, cognitive style and attitude to practical Biology were investigated to ascertain their influences on the development of the experimental skills. The problem solving approaches employed in the study were Researcher's Experimental Problem Solving Model (REPSOM) and the Traditional Experimental Problem Solving Model (TEPSOM). The results of the study revealed the two experimental conditions (REPSOM and TEPSOM) proved to be a more stimulating and motivational approach to learning than the control condition in the development of cognitive skills, manipulative skills; observational skills; communicative skills and independent and work ethics. The order in which the models improved students achievement was found to be REPSOM > TEPSOM > Control for all the experimental skills except for manipulative skills where the order was TEPSOM > REPSOM > CONTROL. This finding shows that systematic approach to problem solving is effective in boosting students' performance.

Ige, (1998) carried out a study to investigate the relative effectiveness of concept-mapping and problem solving teaching strategies (used singly and in combination) on secondary school students' learning outcomes in Ecology. The results revealed that the cognitive achievement of students as well as their practical skills development in Ecology was higher for those who were taught using the Concept Mapping Strategy (CMS); Problem Solving Strategy (PSS) or the Combined Strategy (CBS) when compared to the traditional teaching method or the Control Group Strategy (CGS). The order of facilitation of the instructional strategies was PSS>CBS>CMS>CGS. It was observed that gender (male and female) did not influence students' cognitive achievement, practical skills and attitude to Ecology. Also, the results showed that the cognitive style of the students (analytical or non-analytical) taken singly was not critical in shaping the overall performance of students in Ecology.

In a closely related study in physics, Orji (1998) investigated the effects of problem solving (used singly) and in combination with concept mapping instructional strategies on students learning outcomes. The study involved 109 senior secondary 2(SS2) students drawn from four randomly selected secondary schools in Oyo Local Government Area of Oyo State. These students were randomly assigned to the three experimental and one control group. The results revealed that the groups exposed to problem solving, concept-mapping used singly and in combination performed significantly better than those of the control group. The order in which instruction facilitated students' achievement in physics was combined instructional strategy (problem solving and concept mapping) followed by problem solving and then concept-mapping.

Chang and Barufaldi, (1999) carried out a study to examine the effects of a problem solving based instructional model on Earth Science Students' achievement and alternative frameworks. A total number of 172 (86 males and 86 females) nineth grade Earth Science students participated in the study. Two intact classes consisting of 86 students each were randomly assigned to the experimental group and to the control group. The experimental group of 86 students was exposed to a six week period of Earth Science instruction using the Search, Solve, Create and Share (SSCS) Problem Solving Model. The traditional instructional method was used to instruct the control group. The study employed a quasi-experimental pretest and post test control group design. An analysis of covariance (ANCOVA) was employed to ascertain the difference between the two groups (experimental and control) on the post-treatment achievement of post-test. The pretest and students' IQ were used as covariates. The results of the study revealed that problem solving based instructional approach made the nine-grade Earth Science student's to perform better than the students who were instructed through the traditional instructional method, especially at the application level. Also, the results of students opinions towards the problem solving based instructional method showed that student in the experimental group and the control group had similar perceptions towards the problem solving approach. However, they all believed that the problem solving based instructional method helped them to developed analytical and observing skills as well as improved their thinking skills.

Akubuilo (2004) investigated the effects of problem solving instructional strategies on students' achievement and retention in Biology. The samples (428 students) were randomly assigned to the two treatment groups: Problem Solving with model and Feedback-Correctives (PF). Problem Solving with Model Only (PM), and the Control Problem Solving Inquiry Model developed by Hungerford (1975). The study showed that students' cognitive achievement and retention in Biology were greatly enhanced by the problem solving with model and Feedback-Correctives (PF) and problem solving with Model only, more than by the conventional method (PC). The hierarchical order of students' achievement was students cognitive PF>PM>PC. Also, there was no significant difference in achievement and retention of Biology as a result of their location (urban or rural). This thus inferred that students cognitive achievement do not depend on the type of environment under which teaching takes place.

Olagunju and Chukwuka, (2008) examined the effects of moral dilemma and problem solving strategies on students' achievement in selected environmental concepts in Biology. Three hundred and sixty senior secondary school two Biology students from six randomly selected secondary schools were involved in the study. A pretest, posttest control group, quasi-experimental design was adopted for the study. One research question and three null hypotheses were raised and tested at 0.05 level of significance. Data collected were analysed using both descriptive and inferential statistics. The findings showed that the problem solving treatment group had the highest adjusted post mean score, followed by the moral dilemma group while the control group had the least mean score. This is possible because problem solving strategy led to clarity in thinking and improved intellectual development in the students.

Orimogunje, (2008) investigated the effect of two problem solving models (Systematic Approach to Problem- solving (SAP) and Problem Based Learning (PBL)) in facilitating students' learning outcomes in chemistry. A non-randomized pretest, posttest control group research design was adopted for the study. The participants consisted of ninety senior secondary two chemistry students drawn from three schools in Akure South Local Government Area of Ondo State. Data collected were analysed using means, standard deviation and Analysis of Variance and post hoc analysis at 0.05 level of significance. The finding showed that the students exposed to systematic Approach to Problem-solving did better than those exposed to Problem Based Learning with the control group having the least performance. However, the study did state the factors or moderating variables that could have contributed to the performance of the students. To ascertain the effectiveness of an instructional strategy it is necessary to include some moderating variables.

Okoye and Okechukwu, (2010) carried out a study on the effect of concept mapping and problem solving teaching strategies on achievement in Biology among Nigerian secondary school students. The study consisted of one hundred and thirteen senior secondary three Biology students randomly selected from three mixed secondary schools located in Delta North Senatorial District of Delta State. A quasi-experimental pretest, posttest treatment design was adopted for the study. Data generated were analysed using

Analysis of Covariance. The results revealed that using problem solving instructional strategy improved significantly the achievement of students in genetics more than the students exposed to the traditional lecture method.

Ince Aka, Guven and Aydogdu, (2010) investigated the effects of problem solving method on science process skill and academic achievement on learners who attended science teaching programme. Results of the study revealed that the experimental group students have higher mean scores than the control group students in post science process skills and post achievement test. This again proves the efficacy of problem solving method over the traditional method.

2.7 Practical Work, Achievement and Science Process Skills in Biology

The need to improve science instruction in schools since the Sputnik 1 era has been the concern of scientist and science educators. After the launching of Sputnik 1, the need to engage students in the learning of science by their active involvement in the teaching and learning process became very necessary. As a result, a number of study reforms were initiated in various parts of the world to actualize this desire. These included, Elementary Science Study, Science- A Process Approach in the United States of America; Nuffield Junior Science Project, Scottish Integrated Science Course, Science 5-13 in the United Kingdom. In Nigeria, two national science curriculum projects were initiated. These were the Nigerian Integrated Science Project (NISP) for the junior secondary school and the Nigerian Secondary Schools Science Project (NISSSP) for the senior secondary school. These science projects emphasize the teaching of science through practical or laboratory activities that should make the learners seek answers to problems generated on their own. Also, these projects were designed to help learners develop good concept formation, high level thinking, curiosity and creativeness. More attention is placed on the learner, how he learns and the means through which information is passed on to him in the teaching environment.

Emphasis is placed on the role of practical work as students will acquire practical skills when they are exposed to laboratory activities. The House of Commons Committee on Science and Technology (2002) stated that practical work including fieldwork is a vital part of science education and that it helps students to develop their understanding of science. Woolnough and Allsop (1985) believed that the fundamental objectives of laboratory work in science is central to the nature of scientific activity, which has to do with the development of scientific skills and techniques along with the development of problem solving ability. In essence, practical work provides the content and process of science. Akale and Usman (1993) summarise the importance of practical work as:

1. providing an important source of motivation for students;
2. being crucial for students' understanding of principles and application of knowledge for cognitive growth and technological orientation

Gott and Duggan (1995) stated that practical activities

1. help students develop experimental skills;
2. enable students apply substantive knowledge to new situations;
3. act as motivational stimuli which promote in students interest and social skills.

Similarly Shaibu and Mari (2000) gave the following as the role of practical work.

1. Laboratory investigative activities stimulate the acquisition of manipulative and cognitive skills by learners.
2. Laboratory activities provide students the opportunity not only to learn about science but to also acquire skills that help them think logically, ask reasonable questions, seek appropriate answers and solve problems.

Practical work carried out by students while solving problems is designed to enable learners tackle and solve problems that confront them, hence students should be given opportunity to observe, handle things and explore the environment. According to Yoloye 2010, problem solving practical work is designed to help learners learn the stages, steps or the heuristics of problem solving procedure. Students are able to develop high order cognitive skills and thus experience the joy of discovery.

Akale and Usman (1993) investigated the effect of practical activities on students' academic achievement in integrated science. The sample consisted of a total of three hundred and twelve Junior Secondary School II students from two male and two female schools in Zaria local Government Area of Kaduna state. The subjects were randomly distributed to experimental and control groups. The experimental group were exposed to the selected topic and the practical activities using the intensive activities strategy while the control group were taught in the conventional way. The results revealed that students who were exposed to more practical activities significantly out-performed those who were taught using the conventional method. This implies that practical activities when built into the lesson thus improve students' understanding of scientific concepts.

Myers and Dyer (2006) carried out a study to determine the effect of investigative laboratory integration on students' content knowledge and science process skills achievement across learning styles. Students were assigned to three treatment groups: subject matter approach without laboratory experimentation; subject matter approach with prescriptive laboratory experimentation and subject matter approach with investigative laboratory experimentation. Results showed that students taught using the investigative laboratory approach or subject matter approach to teaching had higher science process skills gain score than students taught using the prescriptive laboratory treatment level. This again emphasis, that incorporating practical activities into science teaching enhances academic achievement and development of science process skills.

Cossa (2007) investigated the impact of practical work in the teaching and learning of cell Biology concepts and student's perceptions of the role of practical work in the learning of cell Biology. A total of forty-one first-year biology students and eleven biology lecturers participated in the study. The data employed for this study were gathered from pre and post-tests, interviews, classroom observations and questionnaires which were analysed using descriptive statistics and analytical approaches. The results revealed that cell biology practical work improved greatly the students' level of understanding in that they gained the relevant manipulative skills needed to observe, understand and provide adequate explanation for the mitotic and meiotic events by linking theory and practice. The students also developed positive attitudes towards practical work. She therefore suggested that the students' background should be explored before introducing them to new learning materials or equipment as this will afford them the opportunities to develop valid understanding of cell Biology concepts.

Nwagbo and Chukuelu, (2012) investigated the effects of Biology practical activities on secondary school students' process skills acquisition. A sample of one hundred and eleven senior secondary one (SS1) Biology students were randomly drawn from two co-educational schools in Abuja Municipal Area Council were involved in the study. A pretest, posttest non-equivalent control group design was adopted for the study. Two research questions and two null hypotheses were raised and tested at 0.05 level of significance using mean, standard deviation and Analysis of Covariance. The results revealed that practical activity method was more effective in fostering student s' acquisition of science process skills than the lecture method. However, when students are exposed to laboratory activities and are allowed to participate in Biology instruction through practical experience using appropriate teaching strategies such as the application of problem solving instructional strategy as proposed in this study, learners will be more likely to acquire and develop mental processes and skills that are linked up with science achievement particularly in Biology.

The need to assist students develop science process skills is a crucial aspect of science teaching as this helps students practice science as it should be practised. Science educators have stressed the need for students to develop science process skills through the process of problem-solving in suitable learning environment. Gagne (1965) defines science process skills as intellectual skills as well as the learned capabilities which scientist use as self-management procedure in carrying out their scientific activities. This implies that science process skills are the processes scientist use in doing science. These skills make it possible for students to carry out objective investigation and draw conclusions based on results. Science process skills are psychomotor skills and cognitive skills which are employed in problem solving (Akinbobola and Afolabi 2010). These are skills that can be acquired and developed as students take active part in practical activities. Science process skills when applied to practical situation promote transfer of knowledge which is necessary for problem solving and functional living (Akinbobola and Afolabi 2010). Science educators have suggested that the development of science skills should be a major goal of science education (Awodi 1984, Gagne 1968). The acquisition of science process skills must go hand in hand with the acquisition of scientific knowledge. The argument put up by these science educators is that as students acquire science process skills in the course of teaching and learning, the application of these skills in their day to day life will enable them address the problems they encounter, both scientific and social.

Campbell, (1979) identified two aspects of science process skills. These are the basic science process and the integrated science process skills. The basic science process skills is made up of the following component skills, observing, classifying, inferring, measuring, communicating and predicting while the integrated science process skills has the component skills namely, making operational definition, formulating questions and hypothesis, experimenting, identifying variables, interpreting data and formulating models. There is a hierarchical relationship between the broad skills as established by Brotherton and Preece, (1996). Brotherton and Preece emphasized that the acquisition of the basic skills is a pre-requisite for the development of integrated skills.

Ibe, (2004) reported that the American Association for the Advancement of Science developed the Science A Process Approach (SAPA) programme, a programme that identifies science process as the nature of science designed to improve learners skills in the process of science.

Relatively, Lock (1992) identified a number of practical skills which include observation, manipulation, interpretation, planning, report and self reliance. Acquisition of practical skills is an essential goal of science education made possible when laboratory work is carried out using appropriate teaching strategy.

Practical activities in science are designed to help students develop the necessary scientific skills. The objective of Biology syllabus emphasizes students' involvement and active participation in Biology lesson through practical activities. Evidences from research studies have supported the assertion that involvement of students in laboratory activities can enhance the acquisition of practical skills. Science educators are of the consensus agreement that science skills are developed only when appropriate teaching strategies are employed during the laboratory transaction. The teaching strategy used for this study which will incorporate students' involvement in the production of the resource materials can also achieve similar effect. Empirical reports on the use of systematic laboratory activity in helping students develop the necessary science skills are hereby reviewed.

Ikitde, (1994) carried out a study on fostering experimental proficiency of students in Biology using problem solving models. A sample of 210 senior secondary school students (121 boys and 89 girls) of Biology drawn from three secondary schools in three senatorial district of Akwa Ibom state were involved in the study. The results showed that employing well structured problem solving models during Biology practical lesson greatly fostered the experimental proficiency of students in biology in the domain of cognitive achievement cognitive skills, manipulative skills, observational skills, communicative skills, independence and work ethics.

Ibe and Nwosu, (2003) investigated the effects of guided inquiry and demonstration methods of teaching on science process skills acquisition among secondary school Biology students. The design of the study was a quasi-experimental non-equivalent pretest, posttest control group. One hundred and fifty senior secondary one Biology students from three randomly selected co-educational secondary schools in Nsukka Local Government Area of Enugu State were involved in the study. The intact classes were randomly assigned to the two experimental and one control group. The experimental group one and two taught using guided-inquiry and demonstration method respectively, while the control group was taught using the conventional lecture method. Analysis of Covariance was used to test the null hypotheses at 0.05 level of significance. Ibe and Nwosu found out that the use of guided inquiry teaching methods in the classroom helped the students to acquire the science process skills which make the understanding of science concepts easier. The process skills understudied were not spelt out in the study which raised the assumption that all science process skills were considered. This may be too cumbersome to be investigated in one study. It is essential that science process skills or practical skills to be enhanced in a study should be well spelt out as is done in this study.

Raimi and Fabiyi (2008) carried out a study to determine the effect of practical skills teaching on students' learning of chemistry at the secondary school level. A sample of two hundred and eighty six (145 males and 141 females) students drawn from ten randomly selected senior secondary schools in four local government areas of Oyo State were involved in the study. A pretest posttest experimental control design using a 2x2 factorial representation was employed for the study. Data collected for the study was analysed using a 2x2 Analysis of Covariance. Results from the findings revealed that students in the experimental group acquire better practical skills than their counterparts in the control group. Students become better equipped with basic science skills that make them good problem solvers.

2.8 Students' Involvement in the Production of Instructional Materials

The use of instructional materials during Biology lessons provides students with opportunities to interact among themselves, their teachers and the learning materials (Ibe, 2006; Ehikhamenor, 2003). As students interact with learning materials, knowledge and scientific skills which are associated with scientific enquiry are acquired. Learning becomes real and Biology becomes "alive". The classroom teachers have a greater responsibility in determining and in selecting appropriate instructional materials that would promote effectiveness and efficiency of the teaching learning process. It is the responsibility of the classroom teacher to "boost" students' achievement in Biology by ensuring that students participate actively in laboratory activities and that they develop favourable attitudes towards the use of resource materials.

Balogun (1982) identified three educational reasons for using instructional materials during classroom instruction. Students are able to:-

1. develop problem-solving skills and scientific attitudes;
2. acquire scientific appreciation and interest;
3. develop functional knowledge and manipulative skills.

Therefore, it is imperative that teachers should ensure that resource materials are available for teaching.

Students' involvement in the production of instructional materials for teaching them is one crucial strategy that teachers should employ to foster experimental proficiency of students. Students can then integrate their ideas and perceptions with that of their teachers to produce resource materials that can aid their teaching as well as enhance students' understanding. As the students get involved in the production of the resource materials they are to use for learning, they are thus provided with opportunities to find out things on their own which can promote meaningful learning.

Research studies have revealed that students understand biological concepts better when they are taught with resource materials that they produce themselves (Ofoegbu, 2005). Ofoegbu investigated the effects of students' involvement in the production of instructional material on their academic performance in Biology. Forty senior secondary two (SS11) students were taught using the instructional materials they produced and another class of thirty eight senior secondary two (SS11) students were taught using already prepared instructional materials by their teacher. The data was analysed using T-test. The result revealed that the group taught with the resource materials they themselves produced performed significantly better than the control group taught with already prepared resource materials. He therefore suggested that for better performance of students in practical work, they should be encouraged to be involved in the production of instructional materials as this enhances their understanding of parts and their relationships.

2.9 Mental Ability, Achievement and Science Process Skills in Biology

The ability of learners is a variable that many researchers have found to affect achievement (Schiefele and Czikszentmihalyi, 1995; Inyang and Ekpeyong 2000, and Lock, 1992). Biology is concerned with conceptual thinking, abstraction, generalization of facts and many more. These require the application of cognitive (mental) process. Piaget's work on cognitive development emphasized that a child is most likely to attain intellectual development (formal operation stage) at about the age of 12 years. 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. Intelligence is not innate or inborn but can be developed by exposure to varying factors in the environment. It therefore follows that achievement in Biology would require a child's application of his formal reasoning ability together with others, such as, environmental influence and school factors. On the contrary, students may have difficulties in applying knowledge acquired in the class environment to other situations probably because they have not acquired the appropriate cognitive level of comprehension and application. Studies have revealed that students have varying ability levels which affect learning outcomes, (Olagunju and Chukwuka, 2008; Adesoji, 2008; Raimi, 2003 and Adeoye, 2000).

Olagunju and Chukwuka (2008) investigated the effects of moral dilemma and problem-solving strategies on students' achievement in conservation, waste management, pollution and over population concepts in Biology. The study adopted a pretest, posttest control group, quasi-experimental design using 3x3x2 factorial matrix that is, three levels of treatments, three levels of ability groups (high, medium and low) and two levels of gender(male and female). Three hundred and sixty students (210 males and 150 females) from twelve intact classes were drawn from two schools randomly selected from three local government areas of Delta state. The results revealed high mental ability group did better than the medium and low mental ability groups. Furthermore, the high mental ability groups appear to be better equipped intellectually to withstand the mental stress involved in problem solving.

However, Adesoji (2008) investigated the impact of problem-solving instructional strategy on the performance of students of different ability levels in chemistry. One hundred and twenty senior secondary class two chemistry students were selected from four secondary schools in three local government `areas of Osun State. Thirty students were randomly selected from each of the four schools. The participants were stratified into three ability groups of high, medium and low. The pretest scores of the students in the three ability groups were subjected to Analysis of variance. The posttest scores were analysed using Analysis of Covariance. The results showed that there was no significant difference in the performance of students in the different ability groups being exposed to the problem-solving strategy. The students in the three ability groups were able to solve problems based on electrolysis and its prerequisite concepts after treatment.

Nzewi and Osisioma, (1994) in a study designed to find out the relationship between formal reasoning ability, acquisition of science process skills and achievement in science found out that there was a positive relationship between (1) formal reasoning ability and acquisition of process skills (2) formal reasoning ability and science achievement (3) acquisition of science process skills and science achievement.

Studies have also shown that students of varying ability levels perform differently depending on the types of methods and materials used for instruction, (Adesoji, 2008; Fajola, 2000 and Okafor, 1999). It has been observed that students of varying ability level can be motivated to learn and helped to improve upon their thinking abilities when instructional materials and appropriate teaching strategies are employed by the teacher during classroom or laboratory teaching activities (Okafor ,1999; Haung, 1995 and Felder, 1994). It is likely that the problem solving instructional strategies to be used in this study could be applicable to students' learning irrespective of their varying learning capabilities.

2.10 Gender, Achievement and Science Process Skills

2.10.1 Gender Inequality in Education

There is a general outcry over the low percentage of girls who are exposed to education (UNICEF, (1994); UNESCO, 1990) and World Bank (1991). Women have been identified to be the poorest and the most marginalized group of people in the world (Conte, 2000). Conte (2000) further stated that "figures provided by the United Nations, speak of a pitiless plight: 70% of the poor and two-thirds of the illiterate in the world are females." Relatedly, Aina in Umar and Gbana (2004) stated that "nearly one billion adults worldwide cannot read and write and two-thirds of them are women." This was confirmed by BRIDGE (2005) where the percentage literacy rate for females was 87% while that of males was 89%. Similarly, lower percentage rate for enrolment was recorded for females. Females have been grossly under-represented in schools at all educational levels in terms of participation and achievement in science technology and mathematics education (Maduabum, 2006). Those who have the opportunity to be enrolled in schools are readily withdrawn from such schools at the slightest excuse. The Nigerian culture believes in educating the males far and above the education of girls, thus enrolling girls at school last and withdrawing them first, (Mbanefor, 1997).

Several factors have been raised to explain the gender inequalities in educational opportunities that exist in the Nigerian societies. Piwuna (2000) puts such factors to include tradition, religious beliefs, economic factors and parental lackadaisical attitude towards girls' education. Isa (2006) on the other hand attributed females' denial of educational opportunities to factors such as economic, cultural, social, political, religious and educational. Researchers have revealed that women are not only under-represented in science, but their levels of academic achievement in science and technology are low compared to men (Okeke, 2001; Lucy and Nkoyo, 2000; Erinosho, 1994; Tobin and Gernette, 1990). This trend of low participation in science and technology and the associated poor academic performances of female students have been traced to a number of factors. Adesoji, 2002, gave three likely factors which had also been identified by most studies carried out in Euro-America to be biological social and psychological factors.

2.10.2 Studies on Gender, Achievement and Science Process Skills in Biology and other Science Subjects

There has been conflicting reports on gender with respect to performance on practical skills in science. In some laboratory skills, the males tend to perform better while females tend to do better in others.

Lock (1992) compared the performance of students on four problem solving tasks set in science based on gender. Thirty six students (eighteen boys and eighteen girls) were involved in the study. The problem solving tasks were administered in a one-to-one practical activity situation after confirming that the tasks were valid and reliable and the samples of students (boys and girls) were matched for curriculum background as well as for ability. The students' performance of the task was accessed by direct observation, oral responses to questions and the use of written records of results made by the pupils. The results revealed that there were only few significant differences between the performances of boys and girls in practical science skills. However, girls' performance in self-reliance in relation to boys' was significantly low, with boys performing better in the interpretation skill. Generally there were no gender differences in reporting, observation or planning skills. Neither were there differential performances on the use of scientific language. Based on the findings of this study, Lock made the following suggestions.

1. Science lessons, particularly those where a problem is posed, should be structured in such a way that girls are reassured about the appropriate nature of the work they are carrying out.
2. Low-ability girls should be encouraged to take a more active part in science practical activities and should spend less time on preparing to report their procedures.
3. Boys and low-ability boys in particular, should be given greater assistance in recording their results in a systematic manner.

Toh (1993) compared the performances of students in three problem solving tasks. The results indicated that girls distinctly preferred content familiarity and performed better than boys in several science skills in related content. These observed results contradict the general belief that boys are better achievers in science related disciplines.

Oladokun, (2000) investigated the relative effectiveness of concept mapping, analogy and problem solving strategies on students' learning outcomes in some environmental concepts in Biology. The participants involved in the study consisted of three hundred and ninety senior secondary two students randomly selected from four secondary schools in Ibadan metropolis of Oyo state. A pretest posttest control group quasi-experimental design was adopted for the study. The data collected were analysed using Analysis of Covariance. The results showed that gender did not influence the performance of students in environmental concepts in Biology.

Research study carried out by Mari, (2001) on the effect of gender on students' understanding of science process skills in science learning revealed that students possessed low understanding of science process skills. The female students did better than the males in the understanding of science process skills.

Abdullahi (2002) conducted a study involving one hundred and eighty SS 2 Biology students (94 boys and 86 girls) to determine the relative effectiveness of two inquiry teaching approaches (experimentation and problem solving) and the lecture method on students learning outcome in Biology. The subjects for the study were drawn from six randomly selected secondary schools in Dekina Local Government Council of Kogi state. He adopted a 2x2 Analysis of Covariance to test the hypotheses stated with posttest scores as covariate. The result showed that the male students performed better than the female students in the cognitive test.

Olagunju and Chukwuka, (2008) examined the effects of moral dilemma and problem solving strategies on students' achievement in selected environmental concepts in Biology. Three hundred and sixty senior secondary school two Biology students from six randomly selected secondary schools were involved in the study. A pretest, posttest control group, quasi-experimental design was adopted for the study. One research question and three null hypotheses were raised and tested at 0.05 level of significance. Data collected were analysed using both descriptive and inferential statistics. The study revealed that there was no significant effect of gender on students' environmental knowledge in Biology. This means that gender did not influence the learners' performance, probably because this strategy afforded both sexes equal opportunities to be involved actively in the learning process.

Okoye and Okechukwu, (2010) carried out a study on the effect of concept mapping and problem solving teaching strategies on achievement in Biology among Nigerian secondary school students. The study consisted of one hundred and thirteen senior secondary three Biology students randomly selected from three mixed secondary schools located in Delta North Senatorial District of Delta State. A quasi-experimental pretest, posttest treatment design was adopted for the study. Data generated were analysed using Analysis of Covariance. The results revealed that there was no significant difference in the performance of male and female students. This implied that gender does not play any role on students' academic achievement when exposed to the study of genetics.

Nwagbo and Chukuelu, (2012) investigated the effects of Biology practical activities on secondary school students' process skill acquisition. A sample of one hundred and eleven senior secondary one (SS1) Biology students were randomly drawn from two co-educational schools in Abuja Municipal Area Council were involved in the study. A pretest, posttest non-equivalent control group design was adopted for the study. The study revealed that male students had a higher mean score than their female counterpart, although the difference was not significant. The interaction effect between teaching method and gender of the students were not significant. This means that gender did not combine with teaching methods to affect the students' acquisition of science process skills. Earlier studies carried out by Ikitde (1994) and Ige (1998) to determine the effect of problem solving strategy on students' acquisition of practical skills revealed similar result of no significant influence of gender on the acquisition of practical skills.

Researches reviewed had shown that studies on sex and academic performance are inconclusive. However, there are indications that there are possible influence of gender on academic achievement and science process skills thus, establishing a case of possible interaction effect on students' performance in Biology. This presupposed a basis for its inclusion as a moderating variable in this study.

2.11 Appraisal of the Literature

Problem solving is the process of moving towards a goal when the path to that goal is uncertain. It is a basic skill which is very vital to today's learners. Problem solving has been regarded as the linking ties between context and application in a learning environment for the development of basic skills and their uses in all aspect of life (Kirkley, 2003).

A number of problem solving models have been developed to help improve the problem solving behaviour of students in science. Many problem solving models are concentrated in the physical sciences and mathematics with few in Biology (Ikitde, 2004). A learner is required to pass through various steps or stages as suggested in these models to progress from one stage of the identification of the problem to the stage of the solution of the problem. The stages in these models seem to have a general trend but the heuristics involved and the scope of applicability differ. The few problem solving models in Biology may not be completely relevant in dealing with most aspects of Biological concepts, particularly in the aspects of tissues and supporting systems in animals and plants which the researcher intended to address in this study. Hence the need to modify the Researcher's Experimental Problem Solving Model to it make suitable for this study.

The modified problem solving model used for this study is termed Bio Problem Solving Model (BioPSOM). The main distinctive feature in this model is the inclusion of production of instructional materials by the students. Research studies have been carried out using problem solving strategies but none has focussed on the use of problem solving instructional strategy where students used the instructional materials they produced before engaging in problem solving. Besides, the problem solving instructional strategies for this study (Bio Problem-Solving Instructional Strategy and Gayford's Problem-Solving Heuristic) have not been previously used for problem solving in Biology, neither did the literature reviewed indicate that a study on problem solving instructional strategy designed for students' individual work and co-operative work in Biology Practical had been carried out in Nigeria.

The importance of employing problem solving instructional strategies had been emphasized by science educators. Research findings revealed that students become better equipped with basic science skills that make them good problem solvers when such skills are incorporated into laboratory instructions (Ince Aka, Guven and Aydogdu, 2010; Raimi and Fabiyi, 2008). It also showed that the strategy greatly enhanced students' achievement, (Okoye and Okechukwu, 2010; Orimogunje, 2008; Olagunju and Chukwuka, 2008; Adesoji, 1991) as well as practical skills acquisition (Ikitde, 1994 and Ige, 2001). The prevailing poor performances of students in Biology examination suggest that a self-activity based instructional strategy which involves the use of instructional materials produced by the students in the learning process during problem solving would be a viable option for addressing problems associated with students' academic achievement and lack of science process skills in Biology. This is what this study seeks to address.

Biology is concerned with conceptual thinking, visualisation and abstraction, manipulation of apparatus and generalisation of facts. Biology practical involves great mental activities that require students' cognitive ability to be consistent with correct reasoning, ask reasonable questions, think critically, seek appropriate answers and solve problems of an experimental nature and these depend on students' cognitive abilities. Science educators have indicated that mental ability is an important variable that could influence learners' academic performance (Adesoji, 2008; Raimi, 2003 and Salami, 2000). Research findings indicated that students of high mental ability do consistently perform better in academic performance than the other mental ability groups, (Olagunju and Chukwuka, 2008). However, researchers which include, Adesoji, (2008) and Haung (1995) observed that though students are of varying mental ability, they can be motivated to learn and helped to achieve high standard if appropriate teaching strategies are employed by the teacher during teaching transaction. It is hoped that problem solving strategies to be used in this study could be applicable to students' learning irrespective of their varying learning capabilities.

Gender influence on academic achievement and science process skills acquisition has generated much concern among researchers with divergent opinion as to whether gender influence on academic performance is significant or not. Raimi, (2003) and Orji, (1998) found out that gender can influence achievement while Bilesanmi-Awoderu, (2002) reported gender influence on practical skills. However, other research findings revealed that gender does not affect achievement, (Okoye and Okechukwu, 2010 and Oduwaiye, 2009) and science process skills in Biology (Nwagbo and Chukuelu 2012 and Lock 1992). Consequently, there is an inconclusive report on the influence of gender on students' achievement and science process skills which makes gender imperative for further investigation.

CHAPTER THREE

METHODOLOGY

3.1 Research Design

The design adopted for the study is a 3 x 3 x 2 pretest, posttest control group in a quasi-experimental setting. Three intact classes (2 experimental and a control) were involved in the study. Participants in each of the groups were pre-tested on the dependent variables and thereafter exposed to the different treatments.

The research design is diagrammatically represented below in Figure 3.0 using symbols.

O_1	X_I	O_4	E_1	Experimental group 1
O_2	X_2	O_5	E_2	Experimental group 2
O_3	X_3	O_6	C	Control group

Figure 3.0: Research Design

Where

O_1, O_2, O_3 = Pretest scores of the experimental and control groups.

O_4, O_5, O_6 = Post test scores of the experimental and control groups.

E_1, E_2 = Experimental groups

C = Control group

X_1 represents Bio Problem Solving Instructional Strategy

X_2 represents Gayford Problem Solving Heuristics

X_3 represents Modified Lecture Method

The Factorial Matrix which shows treatment at 3 levels (2 experimental and 1 control), gender at 2 levels (male and female) and mental ability at 3 levels (high, medium and low) is represented in Table 3.1

Table 3.1. 3 ×3 ×2 Factorial Matrix

Treatment	**Gender**	**Mental Ability**		
		Low	Medium	High
1. Bio Problem Solving Instructional Strategy (BioPSIS)	Male			
	Female			
2. Gayford Problem Solving Heuristics (GPSH)	Male			
	Female			
3. Modified Lecture Method	Male			
	Female			

3.2 Variables in the study

1. **Independent variable**

The independent variable which is the method of teaching varies at 3 levels as follows:

(a) Bio Problem-Solving Instructional Strategy

(b) Gayford Problem-Solving Heuristics

(c) Modified Lecture Method

2. **Moderator variables**

These are:-

(a) Gender (male and female)

(b) Mental ability (high, medium and low)

3. Dependent variables

These are:

(a) Achievement in Biology Practical

(b) Science Process Skills in Biology Practical

The variables in the study are represented in Table 3. 2

Table 3.2. Variables in the Study.

Independent Variables	**Moderator Variables**	**Dependent Variables**
Method of teaching at three Levels		Learning outcomes
1. Bio Problem-Solving Instructional Strategy 2. Gayford Problem-Solving Heuristics 3. Modified Lecture Method.	1. Gender (male and female). 2. Mental ability (high, medium and low)	Post-test scores from: 1. Achievement in Biology Practical 2. Science Process skills in Biology Practical

3.3 Selection of Participants

Random sampling technique was used in the selection of the three local government areas and in the selection of nine co- educational secondary schools in Ibadan. The participating students were drawn from the Senior Secondary School 2 (SS2) Biology students in the schools. Eight hundred and twenty eight (828) Biology students drawn from nine (9) co-educational secondary schools were involved in the study. The students from each school were located in intact classes. The number of students in each intact class ranged from 65 to 70 students.

The following criteria were used for the inclusion of schools in the study:

1. Co-educational schools
2. Schools where students have been taken through the theoretical background of the mammalian skeleton and tissues in plants in their JSS class.
3. Schools that have been presenting candidates for the Secondary School Certificate Examination (SSCE) and the National Examination Council (NECO) for not less than five years.
4. Schools with qualified teachers (graduate teachers) teaching Biology at the Senior Secondary School Class.
5. Schools willing to grant permission for their schools to be used for the study.

Rationale for the Choice of SS2 Participants for the Study

The choice of Senior Secondary 2 (SS2) students was based on the fact that they have the basic pre-requisite knowledge of the mammalian skeleton and tissues in plants. This places them in a better position to respond adequately to the treatment proposed for this study.

Besides, SS2 students do not have any approved external examination such as SSCE or NECO examination thus, the researcher will be able to have their full co-operation and attention. Also, the students' participation in the research will help them to develop more practical skills that will help prepare them for expected enhanced performance in external examinations such as the SSCE and NECO examinations. Thus, using SS2 students is most appropriate for this study.

Rationale for the Choice of Topics for the Study

There are very limited literature on work done on Tissues and Supporting System in Plants and Animals in Biology. West African Examination Council Chief Examiner's reports (1990, 1992, 1995, 1999 and 2002, 2011) emphasized the inability of students to answer practical questions drawn from Tissues and Supporting Systems in Plants and Animals particularly from the Skeletal System correctly. The poor performance of students at practical examination has been attributed to the inadequate instructional strategy (Okafor and Okeke, 2006) that has been employed at helping students acquire the essential skills necessary for solving problems of a practical nature, thus, the researcher's interest in this aspect of Biology as she modified and developed a problem-solving model. The instructional strategy drawn from the model when used during practical lesson may motivate students and help them overcome their weaknesses in understanding the skeletal system in particular. However, the model can also be applicable for teaching other topics in Biology and the other science subjects.

3.4 Research Instruments

The following instruments were used in the study

1. Achievement Test in Biology Practical (ATBP)

2. Science Process Skills Test (SPST)
3. Science Process Skills Assessment Inventory (SPSAI)
4. Mental Ability Test
5. Teachers' Instructional Guide on Problem Solving Instructional Strategies
6. Teachers' Instructional Guide on Modified Lecture Method
7. Guidelines for Evaluating Teachers' Performance on the Use of Problem Solving Instructional Strategies.

3.4.1 Achievement Test in Biology Practical (ATBP)

This is a thirty item-multiple choice objective test designed to measure the achievement of students in Practical Biology before and after the treatment.

The behavioural objectives of the lesson served as criteria for the selection of the test items. The test comprised of three sections.

Section A: Demographic information of students

Section B: Instructions guiding the procedure of the test

Section C: The test items

The topics and sub-topics for the study are outlined below as spelt out in the SS2 Biology Syllabus.

Topic: Tissues and Supporting System in Plants and Animals

Sub-topics:-

1. Mammalian Skeleton
   - i. Bone of the vertebral column.
   - ii. Girdles and the long bones of the appendicular skeleton.
   - iii. Mechanism of support and movement in animals.
   - iv. Functions of the animal skeleton.
2. Types of supporting tissues in plants.
3. Mechanism of support in plants and functions of supporting tissues in plants.
4. Dentition in mammal, for example, types of teeth, structure of a tooth.
5. Feeding and digestive adaptation in rabbit, (herbivore).

Construction of Achievement Test in Biology Practical

On the basis of the sub-topics selected for the study, 30 objective items (Appendix 1) were constructed. Each test item had five alternative answers A-E. The test items were generated around three levels of cognitive domain, which are, remembering, understanding and thinking. This is in line with Blooms (1956) taxonomy as modified by Yoloye (1984), and had been successfully used by Adegoke (2002); Orukotan (1999); Ikitde, (1994) and Olarewaju (1984). Table 3.3 reflects the Table of Specification showing the three levels of cognitive domain and the number of test items drawn from the sub-topics under each.

Table 3.3. Table of Specification for Achievement Test in Practical Biology

Content	Levels			
	Remembering	Understanding	Thinking	Total
1. Mammalian skeleton, bones of the vertebral column	1	2	2	5
2. Girdles and the long bones of the appendicular skeleton.	1	1	2	4
3. Mechanism of support and movement in animals.	1	1	2	4
4. Functions of the animal skeleton.	1	2	2	5
5. Types of supporting tissues in plants	1	1	1	3
6. Mechanism of support in plants and functions of supporting tissues in plants	1	1	3	5
7. Dentition in mammals. Types of teeth, structure of a tooth	-	-	1	1
8. Feeding and digestive adaptations in rabbit.	1	1	1	3
Total	7	9	14	30

The items were drawn on the basis of how important the various levels apply to problem solving skills. Test items on remembering which requires the learner to merely recall facts without thinking were fewer, followed by test items on understanding (comprehension and application). However, more test items were drawn from the cognitive level "Thinking" (which reflects the aspect of analysis and synthesis). The reason is that practical work involves students to reason and think logically.

Validation of Achievement Test in Biology Practical (ATBP)

Thirty eight item- multiple choice objective tests were scrutinized by my supervisor, Prof E. Adenike Emeke, three Biology teachers from senior secondary schools and two educational experts from the Department of Teacher Education, University of Ibadan for content validity and thirty six test items were found to be adequate. The test items were pretested on a sample of thirty students drawn from schools other than those chosen for the study. The responses were subjected to item analysis which involved finding the item difficulty and item discrimination index. The test items that were found to be too difficult or too easy were removed leaving a total of thirty. Kuder-Richardson Formula 20 was used to calculate the reliability of the test. The value obtained was 0.84.

Scoring of Achievement Test in Biology Practical (ATBP)

Scoring of Achievement Test in Biology Practical (ATBP) was executed by assigning 1 mark to a correct response. The total number of right responses made up the actual score for each student. The maximum score a student could obtain from ATBP was 30 marks

3.4.2 Science Process Skills Test

Students were exposed to a practical test where they were required to carry out practical activities using a number of specimens (mammalian skeleton and plant tissues). Students demonstrated the science process skills as they carried out the practical activities. The science process skills demonstrated by the students were measured using the Science Process Skills Assessment Inventory.

3.4.3 Science Process Skills Assessment Inventory

The Science Process Skills Assessment Inventory was developed to assess students' practical task based on direct observation as they carried out their laboratory work which Ikitde (1994) called "on the spot" assessment. The Science Process Skills Assessment Inventory was used to determine the students' ability on manipulative, observation and communication skills. "On the spot" assessment inventory measures students' ability on a 3- point continuum ranging from zero for total inability to exhibit the skill, 1 for partial exhibition of the skill being measured and 2-point for full exhibition of the skill.

Scoring of the Science Process Skills Test

Scoring of the Science Process Skills Test was in the two parts.

(i) Scoring of the cognitive skill of the laboratory work.

The score for each question depended on the nature and content of the test area that was examined. The scoring guide showed the distribution of scores for each answer to the question. The total score for cognitive skill was 40 marks.

(ii) Scoring of the manipulative, observation and communication skills using the Science Process Skills Assessment Inventory.

The skills assessed (manipulative, observation and communication) were described by some criteria (appendix IV). These criteria were scored on a 3-point continuum ranging from 2 to 0, which is:

2 points for full exhibition of the skill,

1 point for partial exhibition of the skill and

0 (zero) for total inability to exhibit the skill being measured

The trained biology teachers and the laboratory assistances scored the students using the Science Process Skills Assessment Inventory on 3-point continuum as the students carried out the practical work. The total score for the inventory was 30 marks for the 15 items. Thus, the Science Process Skills Test carried a total of 70 marks.

Validation of Science Process Skills Test

The Science Process Skills Test, the Scoring Guide and the Science Process Skills Assessment Inventory were given to my supervisor, graduate science teachers in senior secondary schools and university educators to examine the content validity of the test and the adequacy of the scoring guide. The test-retest method was used to calculate the reliability of the test. This involves administering the test to the same group of students twice within an interval of two weeks. The scores obtained from the two sets of tests were used to compute the correlation coefficient and the value of 0.81 was obtained.

3.4.4 Mental Ability Test

Mental ability test developed by the Australian Council for Educational Research was the instrument used to measure the mental ability of learners. It is made up of forty-two (42) items. In studies carried out by Abimbade, 1987; Orukotan, 1999 and Adekunle, 2005, it was observed that this test has the capacity to discriminate between high and low ability participants. The researcher however modified the mental ability test for its update. To accomplish the re-validation the researcher re-examined the forty-two (42) test items. The researcher edited the constituent parts of the test by reviewing and critiquing each test item with a view to detecting and modifying technical errors. Critiquing is with respect to clarity and consciousness of the item, language, correct answer and distracter. The researcher came up with thirty-six (36) items.

Validation of Australian Council for Educational Research (ACER) Test.

The test items were pretested on SS 2 students other than those chosen for the study. The test items were pretested on two separate occasions within two weeks interval on SS2 students. The Mental Ability is in Mathematics and English Language. The two sets of scores were analysed using Alternate/Parallel Forms to ascertain the reliability coefficient of the test. The reliability coefficient of 0.86 was obtained

Scoring of Australian Council for Educational Research (ACER) Test

The total correct scores for each student in the ACER test were noted. These scores were used to classify students into high, medium and low ability groups. The total score for Mathematics and English language is 72 (36 marks for each subject). Therefore, the participants who scored 60% and above on the ACER test were assigned to high mental ability group, those who scored 40% to 59% were assigned to medium ability group while those who obtained less than 40% were placed in low mental ability group.

3.4.5 Teachers' Instructional Guides on Problem Solving Instructional Strategies

This is in two phases.

Phase 1: Introductory phase: This deals with giving students information relevant to the problem before problems are presented to the students. The presentation follows a typical lesson plan. These are:

(a) Introduction: Introduction of the topic the students are to learn with a review of previous lesson.

(b) Presentation of knowledge or theoretical base. Teacher leads and direct teaching on the topic to be learnt.

Phase 2: Implementation of the Problem Solving Instructional Strategy. This is concerned with the use of the Problem Solving Instructional Strategy using the steps of the Bio Problem Solving Model (BioPSOM) and Gayford Problem Solving Heuristics (GPSH).

(A) Bio Problem Solving Model (Fig 3.1).

Each step was broken down to include specific teacher questions and students' activities that led to the solution of the problem.

Step 1: Recognition of Problem

- Teachers present a problem situation.
- Students examine the problem and say what they can make out of the problem
- Teachers ask more questions to make the problem statement clearer.

Step 2: Gathering and processing Information.

- Students made to recall pieces of information from the lesson previously learnt.
- Students write down in their notebooks general principles or theories and facts that can help them in the problem solving process.
- Students write or talk about the instructional resources needed for the laboratory activities.
- Students suggests how best to obtain these instructional resources.

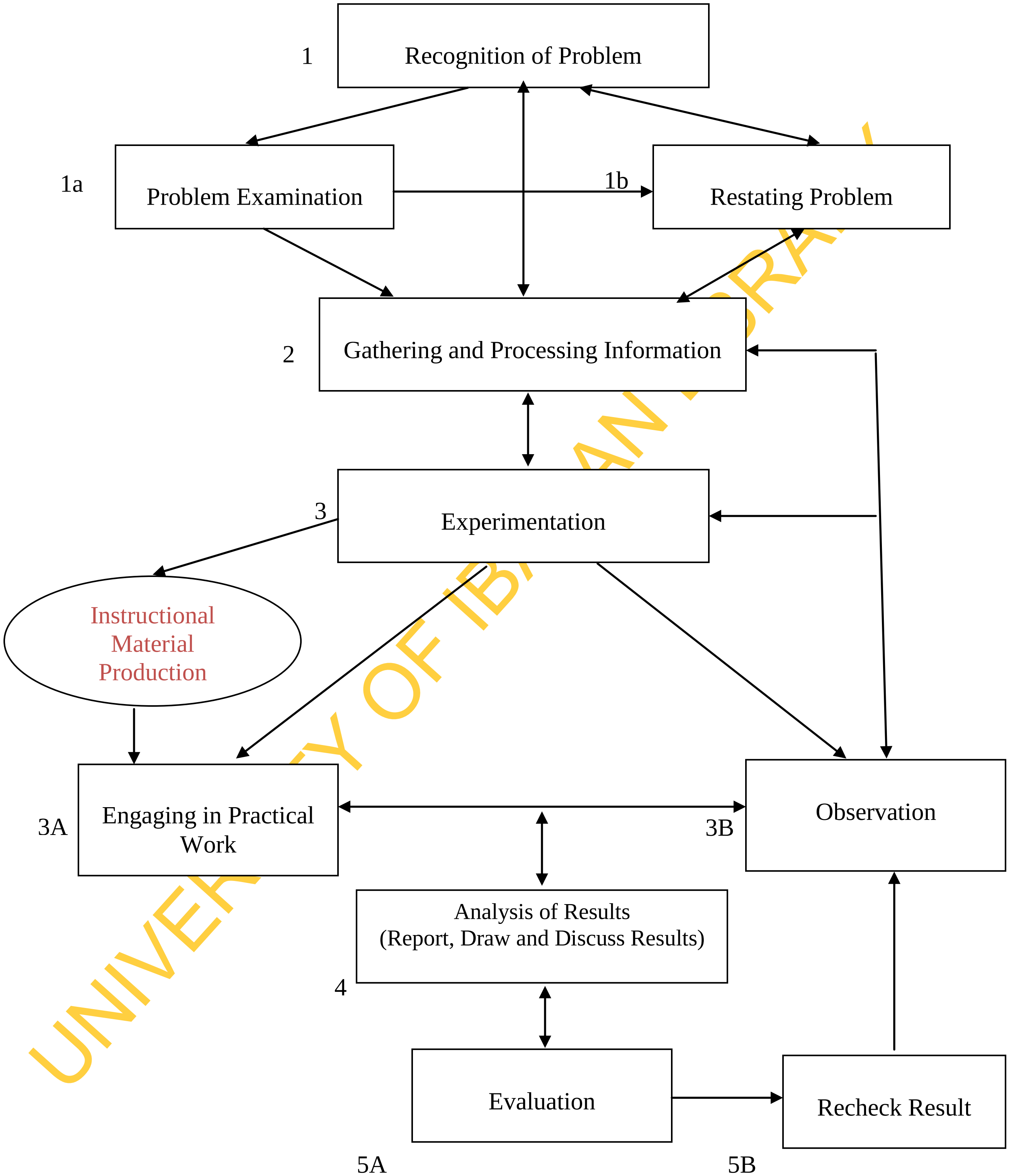


***Figure 3.1: Bio Problem Solving Model (BioPSOM)*.** **Adapted from Researcher's Experimental Problem Solving Model (1994)**

Step 3: Experimentation.

- Students prepare the instructional materials for the practical activities. (This can be done before the commencement of the laboratory activities especially if the material production would take a long time as in the production of the mammalian skeleton)

A. Individual practical work

- Each student collects the instructional materials needed for the practical work in order to solve the problem.
- Students engage in practical activities.
- Each student demonstrates skills (manipulative, communication and observation) in the course of problem solution.

B. Observation.

- Students take note of all experimental happenings.

Step 4: Analysis of Result [Report, Draw and Discuss Result].

- Students make a report of the experiment
- Teacher guides students as they draw and label their drawings.
- Students discuss their results.

Step 5: Evaluation.

- Teacher asks students questions to assess students' knowledge outcomes and practical skills acquired.
- Students evaluate their problem solving process.

(B) Gayford Problem-Solving Heuristics.

1. Grouping of students.
   - Teacher puts the students into groups of ten each.
2. Question and problem generation
   - Students are exposed to problem situation.
   - They discuss this question in their groups.
   - Students write down exactly what they think the problem is.
   - Students think about how someone else is likely to judge how successful they have been in solving the problem. They write this down.

3. Students refer to what they have learned which may help them in problem solving.
4. Experimentation
   - Students select appropriate strategy for the solution of the problem.
   - Students carry out activities using the materials provided by their teacher.
   - Groups assess their choice of strategy and make minor or major changes.
   - Students try to identify any further problem they need to investigate before arriving at the solution.
5. Evaluation – Each group's success is measured by the teacher.

3.4.6 Teachers' Instructional Guide on Modified Lecture Method

- The teacher presents the lesson in the form of lecture.
- Students sit listening to teacher's teaching as he or she gives them the facts.
- The teacher explains and carries out the experiments.
- The students may carry out confirmatory type of practical activity.
- The students ask the teacher some questions on areas where they have difficulties.
- Summaries of the lesson are written on the chalkboard for the students to copy.
- Students are given assignments in preparation for the next

Validation of Teachers' Instructional Guides

The Teachers' Instructional Guides were sent to my supervisor, Biology teachers, Biology educators for evaluation and assessment. The corrected version was produced for use during instruction.

3.4.7 Guidelines for Evaluating Teacher's Performance during Training on the use of the Instructional Strategies

These were used to evaluate the trained teachers' effective use of the instructional guides. The guide was made up of the different traits/stages of the instructional strategy to be assessed

3.5 Procedure for the Study

The procedure for the study followed the outlined sequence of activities.

1. Training of facilitators
2. Administration of Pretest
3. Instructional material production
4. Administration of treatment in the experimental and control groups
5. Administration of Post test

3.5.1 Training of Facilitators

The researcher obtained introductory letters from the Head of Department of Teacher Education, University of Ibadan, to the principals of the participating schools soliciting for permission to use their schools for the research study.

The first two weeks of the study was devoted to the training of Biology teachers. These teachers were taught how to implement the Problem Solving Instructional Strategies, the Modified Lecture Method, the Laboratory Skills Assessment Inventory and Scoring Guide designed by the researcher for the study. Nine co-educational schools were used for the study. Nine Biology teachers were trained; one Biology teacher for each of the schools that implemented the instructional strategies. Nine training sections for the participating teachers were conducted in the nine secondary schools where the study took place. Each teacher was trained in his/her school. The free periods of the teachers in the participating schools were devoted to the training exercise. The participating teachers were assessed at the end of the training using the guidelines for evaluating the teacher's performance. Two laboratory assistants and one biology teacher (other than the facilitator) in the schools where the study took place were trained in their respective schools on how to use the Science Process Skills Assessment Inventory.

3.5.2 Administration of Pretest and Placement Test.

One week was used for the administration of the pretests using the Achievement Test in Biology Practical (ATBP) and Science Process Skills Test on Tissues and Supporting System in animals and plants. Within the same week, the Australian Council for

Educational Research (ACER) test was administered to the students. The scores the students obtained in the Australian Council for Educational Research (ACER) test were used in placing students in ability groups (High, Medium and Low).

3.5.3 Instructional Material Production

The production of instructional materials used for practical activities was done by the students in the Bio Problem Solving Instructional Strategy group (experimental group one). The procedure for the production of the instructional materials is on appendix XI. The students were supervised by their teachers who were trained for the study. This lasted for a week.

3.5.4 Administration of Treatment.

The study involved two treatment and one control groups. Bio Problem-Solving Instructional Strategy groups consisted of 158 males and 170 females; Gayford Problem-Solving Heuristics comprised of 113 males and 120 females and Modified Lecture Method was made up of 92 males and 175 females. The students involved in the study were of varying mental abilities (High, Medium and Low).

Procedure for Experimental Group 1: Bio Problem-Solving Instructional Strategy

Teacher presented a problem situation.

1. Students were to go over the problem statement if they failed to recognise the problem.
2. Students referred to their theoretical knowledge in forms of facts, principles theories (and strategies) relevant to the problem. The teacher could help students draw on their knowledge by asking relevant questions or making statements to guide their thinking and investigation.
3. Students prepared instructional materials (before or during laboratory activities).
4. Students engaged in practical activities using the instructional materials they produced as they solve the problem.
5. Students demonstrated the skills during laboratory session.

6. Students observed and took note of all details of the experimental happenings as well as all the details on the mammalian bones and plant tissues.
7. Students wrote reports of their observation.
8. Teacher guided students as they drew and labelled their drawings. Students discussed their results.
9. Teacher asked students questions to assess students' knowledge outcomes and science process skills acquired
10. Teacher gave students assignment to prepare them for the next lesson.

Procedure for Experimental Group 2: Gayford Problem-Solving Heuristics

1. Teacher put the students into groups of ten each.
2. Problem was presented to the students
3. Students wrote down the questions they wanted to ask.
4. They discussed this question in their groups.
5. Students wrote down exactly what they thought the problem was.
6. Students thought of how someone else was likely to judge how successful they had been in solving the problem. They wrote this down.
7. Students referred to what they had learned which might help them in problem solving.
8. Experimentation: Students carried out activities using materials provided by the teacher.
9. Students discussed among themselves to find out if the experimental procedure was appropriate or if they needed to make minor or major changes.
10. Students tried to identify any further problem they needed to investigate before arriving at the solution.
11. The success of the group is measured by the teacher.

Procedure for the Control group: Modified Lecture Method

Teachers in the control group were also trained and were given guidelines for instruction on the same topics used for the experimental group. The steps are

1. The teacher introduced the lesson by asking questions on relevant prior learning.
2. Teacher explained or gave the facts as regards the topic to be learnt

3. Teacher described the experiment/ investigation.
4. Teacher carried out practical work.
5. Students might carry out practical work to confirm experiments
6. Students reported what they have been told by the teacher.
7. Teacher asked a few general questions.
8. Teacher concluded the lesson by giving the students notes.
9. Assignments may be given.

For uniformity, lesson plans were prepared by the researcher for the use by all the teachers in all the treatment groups.

Treatments lasted for eight weeks.

3.5.5 Administration of Posttests

Post tests were administered on all the groups (experimental groups and control group) at the completion of treatments. The same instruments used for pretest were also used as post tests. The administration of post tests lasted for one week. On the whole, a total of thirteen weeks was used for the study.

3.6 Method of Data Analysis

The data was analysed using Mean, Standard Deviation and Analysis of Covariance (ANCOVA) with the pretest achievement and science process skills scores as covariates. The Pairwise Comparison Post hoc test (Least Significant Difference) was used to determine which group differs significantly among the three treatment groups (Bio Problem-Solving Instructional Strategy, Gayford Problem-Solving Heuristics and Modified Lecture Method). Graphs were drawn to explain the interaction effects.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter presents the results of the study. The results are presented in the order in which the hypotheses were tested. The results were interpreted at 0.05 level of significance.

4.0 Testing of Hypotheses

4.1a Effects of Treatment on Students' Achievement in Practical Biology

$H0_1$: There is no significant main effect of treatment on students' achievement in Practical Biology.

To test this hypothesis, descriptive statistics, ANCOVA and Pairwise Comparison post hoc test were employed and they are presented in the following tables.

Table 4.1. Descriptive Statistics of Achievement Scores for Treatment Groups and Control

		Pretest Mean Score	Posttest Mean Score		95% Confidence Interval	
Treatments	**N**	**Mean**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Bio Problem-Solving Instructional Strategy	328	9.38	19.68	3.61	19.25	20.12
Gayford's Problem-Solving Heuristics	233	5.94	19.73	3.66	19.25	20.23
Modified Lecture Method	267	8.68	17.89	3.08	17.32	18.47

Table 4.1 shows the descriptive statistics on treatment. The results show that students in Gayford Problem-Solving Heuristics group had a post achievement mean score ($\bar{X}$= 19.73) in practical Biology and students exposed to Bio Problem-Solving Instructional Strategy had a post achievement mean score ($\bar{X}$=19.68) while students in the control

group (Modified Lecture Method) had the least performance with an achievement mean score ($\bar{X}$=17.89).

Table 4.2. Summary of Analysis of Covariance (ANCOVA) of Achievement Scores by Treatment, Mental Ability and Gender.

Source of Variation	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig**	**Eta Squared**
Corrected Model	1404.703	18	78.039	6.690	.000*	.130
Intercept	22014.563	1	22014.563	1887.281	.000*	.700
Pretest	7.924	1	7.924	.679	.410	.001
Treatments	345.555	2	172.777	14.812	.000*	.035
Mental Ability	59.704	2	29.852	2.559	.078	.006
Gender	9.764	1	9.764	.837	.361	.001
Treatment x Mental Ability	201.824	4	50.456	4.326	.002*	.021
Treatment x Gender	41.766	2	20.883	1.790	.168	.004
Mental Ability x Gender	15.213	2	7.607	.652	.521	.002
Treatment x Mental Ability x Gender	45.610	4	11.403	.978	.419	.005
Error	9436.741	809	11.665			
Total	311500.000	828				
Corrected Total	10841.444	827				

[a.] R Squared = .130(Adjusted R Squared = .110)

Table 4.2 presents the summary of Analysis of Covariance (ANCOVA) of tests between- subject effects and it shows that the observed mean difference among the three treatment groups was statistically significant, F (2,809) =14.812; p<.05, partial eta squared n^2 = .035. Therefore, the effect size (3.5%) of treatments on students' achievement in Practical Biology was fair. This means that there is statistically significant main effect of treatments (Bio Problem-Solving Instructional Strategy, Gayford Problem-Solving Heuristics and Modified Lecture Method) on students' achievement in Practical Biology. The null hypothesis was therefore rejected. In order to determine which group differs significantly among the three treatment groups, Pairwise Comparison Post hoc test (Least Significant Difference (LSD)) was conducted and the results are presented in Table 4.3.

Table 4.3. Pairwise Comparison Post Hoc Test for Treatment Groups and Control in Achievement Scores.

					95% Confidence Interval for Difference	
(I) Treatments	**(J) Treatment**	**Mean Difference**	**SD**	**Sig**	**Lower Bound**	**Upper Bound**
Bio Problem-Solving Instructional Strategy	Gayford's Problem-Solving Heuristics	-.054	.354	.878	-.749	.640
	Modified Lecture Method	1.787*	.364	.000	1.072	2.502
Gayford Problem-Solving Heuristics	Bio Problem-Solving Instructional Strategy	.054	.354	.878	-.640	.749
	Modified Lecture Method	1.841*	.391	.000	1.074	2.608
Modified Lecture Method	Bio Problem-Solving Instructional Strategy	-1.787*	.364	.000	-2.502	-1.072
	Gayford's Problem-Solving Heuristics	-1.841*	.391	.000	-2.608	-1.074

Note * Mean difference is significant at p < .05

Table 4.3 shows that students in the two experimental groups (Bio Problem Solving Instructional Strategy and Gayford Problem-Solving Heuristics differ significantly from students in the control group. Students in Gayford Problem-Solving Heuristics did better than those in Bio Problem-Solving Instructional Strategy but the mean differences between them were not significant. The two experimental treatments were almost the same in their effectiveness on students' performance.

4.1b: Effect of Treatment on Students' Science Process Skills in Biology Practical

$H0_{1(b)}$: There is no significant main effect of treatment on students' science process skills in Biology Practical.

To test this hypothesis, descriptive statistics, ANCOVA and Pairwise Comparison Post hoc test were employed and they are presented in Tables 4.4, 4.5 and 4.6

Table 4.4. Descriptive Statistics of Science Process Skills Scores for Treatment Groups and Control

		Pretest Mean Score	Posttest Mean Score		95% Confidence Interval	
Treatments	**N**	**Mean**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Bio Problem Solving Instructional Strategy	328	7.63	42.80	10.08	41.78	43.82
Gayford's Problem Solving Heuristics	233	6.80	33.71	8.46	32.64	34.79
Modified Lecture Method	267	6.15	26.60	7.42	25.22	27.98

Table 4.4 shows the descriptive statistics on treatments. The results show that students exposed to Bio Problem-Solving Instructional Strategy had the highest post achievement mean score ($\bar{X}$=42.80) in Biology Practical. This was followed by students in Gayford Problem-Solving Heuristics group with a mean ($\bar{X}$=33.71) while the students in the Modified Lecture Method had the least mean score ($\bar{X}$=26.60).

Table 4.5. Summary of Analysis of Covariance (ANCOVA) of Science Process Skills Scores by Treatment, Mental Ability and Gender

Source of Variation	Sum of Squares	Df	Mean Square	F	Sig	Eta Square
Corrected Model	61904.676	18	3439.149	50.849	.000*	.531
Intercept	96000.918	1	96000.918	1419.397	.000*	.637
Pretest	2787.471	1	2787.471	41.213	.000*	.048
Treatments	24672.623	2	12336.311	182.395	.000*	.311
Mental Ability	2473.983	2	1236.991	18.289	.000*	.043
Gender	10.175	1	10.175	.150	.698	.000
Treatment x Mental Ability	1541.588	4	385.397	5.698	.000*	.027
Treatment x Gender	312.473	2	156.237	2.310	.100	.006
Mental Ability x Gender	335.760	2	167.880	2.482	.084	.006
Treatment x Mental Ability x Gender	121.781	4	30.445	.450	.772	.002
Error	54716.725	809	67.635			
Total	1108922.000	823				
Corrected Total	116621.401	827				

[a.] R Squared = .531 (Adjusted R Squared = .520

Table 4.5 shows the summary of Analysis of Covariance (ANCOVA) of tests of between-subjects effects. The table shows that the observed mean difference among the three treatment groups was statistically significant F (2,809) = 182.395, p<.05, partial eta squared n^2 = .311. Therefore, the effect size (31.1%) of treatment on students' practical skills in Biology Practical was very fair. This means that there is a statistically significant main effect of treatments on students' science process skills in Biology Practical. In order to determine which group differs significantly among the three treatment groups, Pairwise Comparison Post hoc test (LSD) was conducted and the results are presented in Table 4.6

Table 4.6. Pairwise Comparison Post Hoc Test for Treatment Groups and Control in Science Process Skills

					95% Confidence Interval for Difference	
(I) Treatments	**(J) Treatment**	**Mean Difference**	**SD**	**Sig**	**Lower Bound**	**Upper Bound**
Bio Problem-Solving Instructional Strategy	Gayford Problem-Solving Heuristics	9.087*	.758	.000	7.599	10.574
	Modified Lecture Method	16.202*	.876	.000	14.482	17.921
Gayford Problem-Solving Heuristics	Bio Problem-Solving Instructional Strategy	-9.087*	.758	.000	-10.574	-7.599
	Modified Lecture Method	7.115*	.890	.000	5.368	8.862
Modified Lecture Method	Bio Problem-Solving Instructional Strategy	-16.202*	.876	.000	-17.921	-14.482
	Gayford Problem-Solving Heuristics	-7.115*	.890	.000	-8.862	-5.368

Note * Mean difference is significant at $P< 0.05$

Table 4.6 shows that students in the Bio Problem Solving Instructional Strategy differ significantly from the other two groups.

4.2a: Effects of Mental Ability on Students' Achievement in Biology Practical

$H0_{2(a)}$: There is no significant main effects of mental ability on students' achievement in Biology Practical.

Table 4.7. Descriptive Statistics of Mental Ability on Students' Achievement in Biology Practical

				95% Confidence Interval	
Mental Ability	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Low	261	18.75	3.60	18.31	19.18
Medium	412	18.95	3.50	18.59	19.31
High	155	19.63	3.83	18.10	20.26

Table 4.7 shows the descriptive statistics on mental ability. The results show that the high mental ability group had the highest mean score ($\bar{X}$=19.63). This is followed by the medium ability group with an achievement mean score ($\bar{X}$=18.95) while the low ability group had the least mean score ($\bar{X}$=18.75).The mean difference between the low and high mental ability group is 0.88; between the medium and high is 0.68 between the low and medium mental ability group is 0.20. However, these mean differences among the groups are not statistically significant F (1,809)= 2.55; p>.05, partial eta squared = 0.006 (Table 4.2). There is no significant main effect of mental ability on students' achievement in Biology Practical. The effect size of 0.6% is extremely small. The null hypothesis was therefore not rejected.

4.2b: Effect of Mental Ability on Students' Science Process Skills in Biology Practical

$H0_{2(b)}$: There is no significant main effects of mental ability on students' science process skills in Biology Practical.

Table 4.8a. Descriptive Statistics of Mental Ability on Students' Science Process Skills in Biology Practical

				95% Confidence Interval	
Mental Ability	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Low	261	31.61	11.91	30.57	32.65
Medium	412	34.45	12.05	33.58	35.32
High	155	37.05	9.25	35.53	38.56

Table 4.8 shows the descriptive statistics on mental ability. The results show that the high mental ability group had the highest mean score ($\bar{X}$=37.05). This is followed by the medium ability group with science process skills mean score ($\bar{X}$=34.45) while the low mental ability group had the least mean score ($\bar{X}$=31.61). The mean difference between the medium and high is 2.60 between the low and medium is 2.84 and between the high and low mental ability groups is 5.44. These mean values are statistically significant F (2,809) =18.289 p < 0.05); partial eta squared =.043 (Table 4.5). There is a significant main effect of mental ability on students' science process skills in Biology Practical. The

effect size 4.3% is fair. The null hypothesis was therefore rejected. In order to determine which group differs significantly among the three mental ability groups, Pairwise Comparison Post Hoc test (Least Significant Difference) was conducted and the results are presented in Table 4.8b

Table 4.8b. Pairwise Comparison Post Hoc Test for Treatment Groups and Control in Science Process Skills

(I) mental ability	(J) mental ability	Mean Difference	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Low	Medium	-2.840*	.691	.000	-4.197	- 1.484
	High	-4.438*	.939	.000	-7.280	-3.60
Medium	Low	2.840*	.691	.000	1.484	4.197
	High	-2.597*	.888	.004	-4.340	-.855
High	Low	5.438*	.939	.000	3.595	7.280
	Medium	2.597*	888	.004	.855	4.340

Note * Mean difference is significant at p <0.5

The results on Table 4.8b show that the mean difference between the low and high ability group, low and medium, and medium and high mental ability groups were significant. However, the high mental ability group did significantly better than the other ability groups.

4.3a: Effect of Gender on Students' Achievement in Biology Practical

$H0_{3(a)}$: There is no significant main effects of gender on students' achievement in Biology Practical.

Table 4.9. Descriptive Statistics of Gender on Students' Achievement in Biology Practical

				95% Confidence Interval	
Gender	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Male	363	19.23	3.72	18.80	19.68
Female	465	18.98	3.54	18.63	19.32

Table 4.9 shows the descriptive statistics on gender. Results of the analysis show that males had higher mean score ($\bar{X}$=19.23) than females ($\bar{X}$=18.98). However, as Table 4.2 shows the mean difference of 0.25 is not statistically significant F (1,809) = 0.837; p >.05; partial eta squared =.001(Table 4.2). There is no significant main effect of gender on students' achievement in Biology Practical. The effect size 0.1% was extremely small. The null hypothesis is therefore upheld.

4.3b: Effects of Gender on Students' Science Process Skills in Biology Practical

$H0_{3(b)}$: There is no significant main effects of gender on students' science process skills in Biology Practical.

Table 4.10. Descriptive Statistics of Gender on Students' Science Process Skills in Biology Practical

				95% Confidence Interval	
Gender	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Male	363	34.24	11.62	33.18	35.29
Female	465	34.50	12.08	33.66	35.39

Table 4.10 shows the descriptive statistics on gender. Results of the analysis show that females had higher mean score ($\bar{X}$=34.50) than males ($\bar{X}$=34.24). However, Table 4.5 shows that the mean difference of 0.26 is not statistically significant F (1,809) =.150; p >.05, partial eta squared =.000 (Table 4.5). There is no significant main effect of gender on students' science process skills in Biology Practical. The effect size 0% was extremely small. The null hypothesis is therefore upheld.

4.4a: Interaction Effect of Treatment and Mental Ability on Students' Achievement in Biology Practical

$H0_{4(a)}$: There is no significant interaction effect of treatments and mental ability on students' achievement in Biology Practical

Table 4.11. Descriptive Statistics of Treatment and Mental Ability on Students' Achievement in Biology Practical

					95% Confidence Interval	
Treatments	**Mental Ability**	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Bio Problem-Solving Instructional Strategy	Low	82	19.77	3.98	19.00	20.54
	Medium	188	20.15	3.41	19.64	20.65
	High	58	19.14	3.69	18.24	20.03
Gayford Problem-Solving Heuristics	Low	84	18.83	3.56	17.99	19.67
	Medium	82	19.47	3.47	18.68	20.26
	High	67	20.91	3.56	20.09	21.73
Modified Lecture Method	Low	95	17.64	3.25	16.92	18.35
	Medium	142	17.22	2.83	16.63	17.81
	High	30	18.83	2.29	17.39	20.28

Table 4.11 presents the summary of mean scores and the standard deviation of students' achievement in Biology Practical using the interaction of treatment and mental ability. From Table 4.2 the observed differences in the mean scores are statistically significant, $F(4,809) = 4.326$, $p < .05$, partial eta squared = .021(Table 4.2). The effect size of 2.1% is fair. The hypothesis was therefore rejected. As a result of the interaction, there is the need to disentangle the interaction. To achieve this, a graph of the mean scores of the students was plotted. The mean scores in Table 4.11 were used to plot the graph in Figure 4.1.

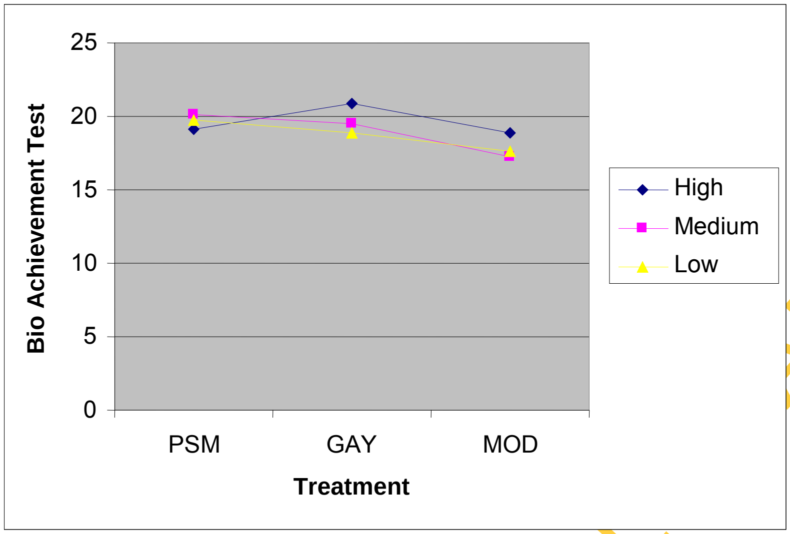


Figure 4.1. Interaction of Treatment and Mental Ability on Students' Achievement

From Figure 4.1, high mental ability students in the Gayford Problem-Solving Heuristics had the highest mean score. This implies that high mental ability students tend to benefit maximally from Gayford Problem-Solving Heuristics. However, for medium and low ability students, Bio Problem Solving Instructional Strategy appears to be their best method.

4.4b: Interaction Effects of Treatment and Mental Ability on Students' Science Process Skills in Biology Practical

$H0_{4(b)}$: There is no significant interaction effect of treatments and mental ability on students' Science Process Skills in Biology Practical.

Table 4.12. Descriptive Statistics of Treatment and Mental Ability on Students' Science Process Skills in Biology Practical

					95% Confidence Interval	
Treatments	**Mental Ability**	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Bio Problem Solving Instructional Strategy	Low	82	42.47	10.04	40.27	44.31
	Medium	188	43.74	10.46	42.56	44.93
	High	58	42.18	8.77	40.05	44.32
Gayford Problem Solving Heuristics	Low	84	29.86	8.23	28.06	31.67
	Medium	82	33.33	7.65	31.51	35.16
	High	67	37.93	6.32	35.96	39.91
Modified Lecture Method	Low	95	22.49	5.89	20.77	24.22
	Medium	142	26.27	6.72	24.85	27.69
	High	30	31.02	10.49	27.54	34.51

Table 4.12 presents the summary of mean score and the standard deviation of students' science process skills in Biology Practical using the interaction of treatment and mental ability. From Table 4.5, the observed differences in the mean score are statistically significant, F (4,809) = 5.698 p > .05, eta squared .043(Table 4.5). The effect size is 4.3% is fair. The hypothesis was therefore rejected.

As a result of the interaction, there is need to disentangle the interaction, a graph of the mean scores of the students was plotted. Mean scores in Table 4.12 were used to plot the graph in Figure 4.2.

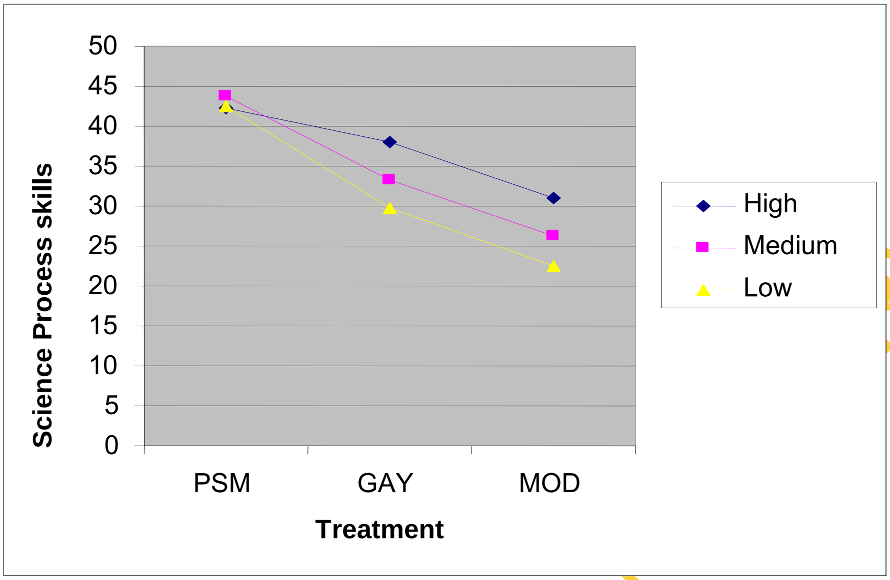


Figure 4.2. Interaction of Treatment and Mental Ability on Students' Science Process Skills in Biology Practical

Medium mental ability students in the Bio Problem-Solving Instructional Strategy had highest mean score. This was followed by the low mental ability students and then the high. In the Gaford Problem-Solving Heuristics and Modified Lecture Method, the high mental ability students had the highest mean score which was followed by the medium and least by the low mental ability students. This implies that high mental ability students tend to benefit maximally from Gayford Problem-Solving Heuristics. However, for medium and low ability students, Bio Problem-Solving Instructional Strategy appears to be their best method.

4.5a: Interaction Effects of Treatments and Gender on Students' Achievement in Biology Practical

$H0_{5(a)}$: There is no significant interaction effect of treatments and gender on students' achievement in Biology Practical

Table 4.13. Descriptive Statistics of Treatment and Gender on Students' Achievement in Biology Practical

					95% Confidence Interval	
Treatments	**Gender**	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Bio Problem Solving Instructional Strategy	Male	158	19.56	3.87	18.94	20.18
	Female	170	19.81	3.35	19.21	20.41
Gayford Problem Solving Heuristics	Male	113	20.20	3.70	19.53	20.86
	Female	120	19.28	3.59	18.61	19.95
Modified Lecture Method	Male	92	17.95	2.99	16.98	18.93
	Female	175	17.84	3.13	17.24	18.44

Table 4.13 presents the summary of mean score and the standard deviation of students' achievement in Biology Practical using the interaction of treatment and gender. On Table 4.2, the observed differences in the mean scores are however not statistically significant, F (2,809) =1.790; $p > 0.05$, eta squared = .004). The hypothesis was therefore not rejected.

4.5b: Interaction Effects of Treatments and Gender on Students' Science Process Skills in Biology Practical

$H0_{5(b)}$: There is no significant interaction effect of treatments and gender on students' science process skills in Biology Practical.

Table 4.14. Descriptive Statistics of Treatment and Gender on Students' Science Process Skills in Biology Practical

					95% Confidence Interval	
Treatments	**Gender**	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Bio Problem Solving Instructional Strategy	Male	158	41.89	9.55	40.42	43.36
	Female	170	43.70	10.48	42.29	45.11
Gayford's Problem Solving Heuristics	Male	113	33.26	9.21	31.71	34.81
	Female	120	34.16	6.87	32.67	35.66
Modified Lecture Method	Male	92	27.55	7.85	25.20	29.91
	Female	175	25.64	7.18	24.21	27.08

Table 4.14 presents the summary of mean score and the standard deviation of students' science process skills in Biology Practical using the interaction of treatment and gender. From Table 4.5 the observed differences in the mean scores are however not statistically significant, $F (2.809) = 2.310$, $p > .05$, eta squared=.006. The hypothesis was therefore not rejected.

4.6a: Interaction Effects of Mental Ability and Gender on Students' Achievement in Biology Practical

$H0_{6(a)}$: There is no significant interaction effect of mental ability and gender on students' achievement in Biology Practical.

Table 4.15. Descriptive Statistics of Mental Ability and Gender on Students' Achievement in Biology Practical

					95% Confidence Interval	
Treatments	**Mental Ability**	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Male	Low	113	19.05	3.60	18.40	19.70
	Medium	177	18.93	3.59	18.37	19.48
	High	73	19.74	4.07	18.73	20.75
Female	Low	148	18.45	3.58	17.87	19.02
	Medium	235	18.97	3.45	18.51	19.43
	High	82	19.52	3.60	18.76	20.27

Table 4.15 presents the descriptive statistics of the interaction of mental ability and gender. The Table shows a marginal difference in the mean score. However from Table 4.2, there is no significant difference in the mean scores of students when the interaction of mental ability and gender are considered $F(2,809) = .652$, $p > .05$, partial eta squared=.002). The effect size of 0.2% is negligible.

4.6b: Interaction Effect of Mental Ability and Gender on Students' Science Process Skills in Biology Practical

$H0_{6(b)}$: There is no significant interaction effect of mental ability and gender on students' science process skills in Biology Practical.

Table 4.16. Descriptive Statistics of Mental Ability and Gender on Students' Science Process Skills in Biology Practical

					95% Confidence Interval	
Gender	**Mental Ability**	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Male	Low	113	30.46	10.95	28.90	32.02
	Medium	177	34.39	11.58	33.05	35.73
	High	73	37.85	8.55	35.42	40.28
Female	Low	148	32.75	12.48	31.40	34.11
	Medium	235	34.51	12.36	33.41	35.61
	High	82	36.24	9.66	34.44	38.05

Table 4.16 presents the descriptive statistics of the interaction of mental ability and gender. The Table shows a marginal difference in the mean scores. However, from Table 4.5 there is no significant difference in the mean scores of the students when the interaction of mental ability and gender are considered F (2,809) = 2.482 p > .05; partial eta squared=.006). The effect size of 0.6% is negligible. The hypothesis was therefore not rejected.

4.7a: Interaction Effects of Treatments, Mental Ability and Gender on Students' Achievement in Biology Practical

$H0_{7(a)}$: There is no significant interaction effect of treatment mental ability and gender on students achievement in Biology Practical.

Table 4.17. Descriptive Statistics of Treatment and Mental Ability and Gender on Students' Achievement in Biology Practical

						95% Confidence Interval	
Treatment	**Gender**	**Mental Ability**	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
Bio Problem-Solving Instructional Strategy	Male	Low Medium High	31 95 32	19.55 19.68 19.46	4.37 3.72 3.91	18.34 18.98 18.27	20.75 20.37 20.65
	Female	Low Medium High	51 93 26	19.99 20.62 18.82	3.77 2.99 3.44	19.05 19.91 17.50	20.93 21.33 20.14
Gayford Problem-Solving Heuristics	Male	Low Medium High	47 32 34	19.24 19.92 21.44	3.27 3.28 4.24	18.20 18.72 20.29	20.28 21.12 22.59
	Female	Low Medium High	37 50 33	18.43 19.03 20.38	3.56 3.47 3.56	17.24 18.05 19.21	19.62 20.01 21.54
Modified Lecture Method	Male	Low Medium High	35 50 7	18.37 17.18 18.32	3.25 2.83 2.29	17.23 16.23 15.78	19.50 18.13 20.85
	Female	Low Medium High	60 92 23	16.91 17.26 19.35	2.78 3.04 3.76	16.04 16.55 17.95	17.78 17.96 20.75

Table 4.17 shows the mean scores of the students' achievement in Biology Practical when the interaction of treatment, mental ability and gender were computed. From Table

4.2, the observed difference is not statistically significant F (4,809) = .978, p > .05, partial eta squared = .005. The effect size of 0.5% is negligible. Therefore the null hypothesis was not rejected.

4.7b: Interaction Effects of Treatments, Mental Ability and Gender on Students' Science Process Skills in Biology Practical

$H0_{7(b)}$: There is no significant interaction effect of treatment, mental ability and gender on students' science process skills in Biology Practical.

Table 4.18. Descriptive Statistics of Treatment and Mental Ability and Gender on Students' Science Process Skills in Biology Practical

			N			**95% Confidence Interval**	
Treatment	**Gender**	**Mental Ability**		**Mean**	**SD**	**Lower Bound**	Upper Bound
Bio Problem-Solving Instructional Strategy	Male	Low	31	40.90	7.34	37.10	43.79
		Medium	95	42.35	10.29	40.68	44.02
		High	32	42.44	9.21	39.57	45.30
	Female	Low	51	44.04	11.26	41.78	46.30
		Medium	93	45.14	10.53	43.46	46.82
		High	26	41.93	8.33	38.76	45.09
Gayford Problem- Solving Heuristics	Male	Low	47	27.70	9.22	25.30	30.10
		Medium	32	33.43	8.51	30.57	36.28
		High	34	38.65	6.51	35.88	41.42
	Female	Low	37	32.03	5.55	29.37	34.69
		Medium	50	33.24	7.14	30.96	35.53
		High	33	37.22	6.20	34.40	40.04
Modified Lecture Method	Male	Low	35	22.79	6.67	20.06	25.53
		Medium	50	27.39	7.52	25.11	29.67
		High	7	32.47	8.62	26.37	38.57
	Female	Low	60	22.20	5.44	20.11	24.28
		Medium	92	25.15	6.15	23.47	26.83
		High	23	29.58	11.10	26.21	32.94

Table 4.18 shows the mean scores of the students' science process skills in Biology Practical when the interaction of treatment, mental ability and gender were computed. The observed difference is not statistically significant F (4,809) =.450, p > .05, partial eta squared = .002(Table 4.5). The effect size of 0.2% is negligible. Therefore, the null hypothesis was not rejected.

4.8 Discussion of Results

4.8.1 Effects of Treatment on Students' Achievement and Science Process Skills in Biology Practical

The results of this study indicated significant main effect of treatment on students' achievement and science process skills in Biology Practical. The result showed that the mean differences between the performance of students exposed to Bio Problem-solving Instructional Strategy (BioPSIS) and Gayford Problem-Solving Heuristics (GPSH) was not significant. Consequently, this implies that the two experimental strategies (BioPSIS and GPSH) were almost the same in their effectiveness on students' performance. Students in the Modified Lecture Method (MLM) had the lowest mean score.

Performance of students in the Bio Problem-Solving Instructional Strategy could have resulted from their being taught with the instructional materials they themselves produced. The students' interaction with their own instructional materials during teaching and learning helped them to understand the biological concepts taught. Similarly, the performance of the students' in Gayford Problem-Solving Heuristics could be due to the discussion the students had in their groups after the teacher's explanation on the theoretical aspects of the concepts studied and this encouraged information exchange during the team work. This finding supports the assertion that Gayford Problem-Solving Heuristics and other cooperative learning during problem solving improves content learning and is essential for knowledge development (Gayford, 1989; Gok and Silay, 2010). Gayford Problem-Solving Heuristics is a strategy that encourages students' participation in class learning in groups where members share ideas and information, seek additional relevant information and solve problems that confront them. The performance of students in the two experimental groups reveals the superiority of Problem Solving Strategy over the Modified Lecture Method (MLM). This is in line with the findings of Okoye and Okechukwu, (2010); Olagunju and Chukwuka (2008); Raimi (2003); Akubuilo (2003, 2004) and Ikitde (1994) who observed that Problem Solving Instructional Strategy is very effective in teaching science concepts, thereby boosting students' performance and retention in Biology.

The result also revealed that students in Bio Problem Solving Instructional Strategy had the highest mean score followed by Gayford Problem-Solving Heuristics and Modified Lecture Method with the least mean score in the development of science process skills. The mean differences between the two experimental groups (BioPSIS and GPSH) could be due to the fact that students in Bio Problem-Solving Instructional Strategy were engaged in individual practical activities while solving the experimental problem as opposed to those in Gayford Problem-Solving Heuristics who were involved in group/co-operative practical activities. This therefore suggests that the involvement of students in individual practical work favoured them in the development of science process skills. This aided the students' performance in the science process skills test thereby making BioPSIS more effective in the development of science process skills in Biology Practical than GPSH and MLM. The advantage of BioPSIS over GPSH in the development of science process skills lies in the fact that BioPSIS promoted in the students the spirit of inquiry and creativity based on individual student's reflective thinking and not as suggested by group members, as well as their ability to follow systematically the application of the problem solving strategy on their own. This made the students to be actively involved in learning by "doing" the practical work. It should be noted that in group practical work, not all students are usually involved in learning by "doing". The work is produced by a few though all those in the group claim the credit of the experimental report. This situation cannot promote the development of science process skill. According to Ince Aka, Guven and Aydogdu (2010); Aktamus and Ergin (2007); Ige (2001) and Ikitde (1994) students' performance in these skills are enhanced when they are given opportunity to carry out individual practical activities. The use of BioPSIS in this study gave credence to their report.

Bio Problem-Solving Instructional Strategy afforded the students the opportunity to interact with the instructional materials they produced, as the stage of material production is a sub-step in the Problem Solving Model designed by the researcher (from which the Problem Solving Instructional Strategy was derived for this study). The use of instructional materials produced by students for teaching has been found to greatly improve students' development of science process skills and achievement. This finding is in line with Akubuilo (2003) who reported that students' performance was greatly enhanced when they used the instructional materials they produced themselves for practical activities. Students high performance using BioPSIS could also have been due to the excitement and enthusiasm students showed when they used the instructional materials they produced for the practical activities and also as a result of the newness of the strategy. This result corroborates the submission of (Olagunju and Ojo, (2006); Agommuoh and Nzewi, (2003); Akubuilo (2003) and Ehikhamenor (2003) that students would learn more if engaged in significant and appealing activities. In addition, students' high performance could have resulted from their ability to adopt a number of steps as in the Problem Solving Model (Figure 3.1) which afforded the students the opportunity to learn through personal experience and connect new information gained during the cause of lesson delivery to what they already know. Although the students in Bio Problem Solving Instructional Strategy did better in the development of science process skills than Gayford Problem-Solving Heuristics and lastly the Modified Lecture Method, the Gayford Problem-Solving Heuristics which emphasized group and co-operative practical work can also enhance students academic performance especially in situation with large class sizes where instructional materials may not be sufficient for individual practical work

Students' poor performances both in achievement and science process skill in the Modified Lecture Method lay credence to the reports of many researchers (Obiekwe, 2008; and Udogu, Ifeakor and Njelita, 2007) who found that the use of this mode of teaching which is teacher-centred does not make students get or become engaged in activities involving manipulation of equipment and materials and that teacher-centred instruction is negatively associated with student achievement in science (Nwagbo, 2006;Von Secker and Lissitz, 1999). Furthermore, Emeke and Adegoke (2006) found that students exposed to learner- centred instruction showed superiority over students who were taught by teachers who dominated the class lesson.

4.8.2 Effects of Mental Ability on Students' Achievement and Science Process Skills in Biology Practical

This study showed that mental ability did not have significant main effect on achievement but had on science process skills scores in Biology Practical. This means that the mental ability level of the students was not an important factor in determining academic achievement since the students in the different ability levels were able to solve the problems. However, mental ability was an important factor in determining the acquisition of the science process skills of students after their exposure to treatments. There was a significant difference in the post science process skills scores of the students in low, medium and high mental ability groups. The results revealed that students with high mental ability had the highest post science process skills test scores, followed by the medium ability students while the low mental ability students obtained the lowest post test mean score in science process skills. These results are in line with the findings of Olagunju and Chukwuka (2008); Morribend (2004) and Rufus (2002) who found positive influence of high mental ability on achievement, while Nzewi and Osisioma (1994) found positive significant influence of high mental ability on practical skills acquisition.

4.8.3 Effects of Gender on Students' Achievement and Science Process Skills in Biology Practical

The results showed that there was no significant effect of gender on students' achievement and science process skills. This implies that gender does not appear to influence achievement and science process skills in the two groups (experimental and control). In other words, students of both sexes benefited from the problem solving instructional strategies in boosting their academic achievement and in the development of science process skills in Biology Practical. It could further be stated that the instructional strategy had about an equal effect on both male and female students. The male and female students were allowed to have equal opportunity to be actively engage in the process of knowledge development. Also, it could be that the problem solving strategy consisted of the essential elements that enhanced both male and female learning hence students equal learning opportunities. This study agrees with the findings of

Okoye and Okechukwu (2010); Obomanu and Nbina (2010); Gok and Silay (2010); Oduwaiye (2009); Akinbobolola and Afolabi (2009); Ibe (2006); Adisa (2002); Ige (2001); Oladokun (2000) and Kanu (1993) who observed that gender did not influence achievement. However, this is at variance with the work of Eze and Afolabi (2011); Ukwangu (2002) and Johnson (2002).

Findings on students' science process skills corroborate with the work of Nwagbo and Chukuelu (2012); Duyilemi (1997) and Ogunsola and Lawan (1996)) who found no significant effect of gender on science process skills but disagree with Njoku, (2006); Bilesanmi-Awoderu (1998, 2003); Mari (2001) who observed that a significant difference exist in gender performance in practical skills. Njoku, Bilesanmi-Awoderu and Mari found that female students performed better than their male counterparts while Butler (2000) hold the view that male students exhibited higher practical skills than their female counterparts. Gender- gap in students' achievement and practical skills in Biology practical is reduced when appropriate instructional strategies are employed during practical lessons.

4.8.4 Interaction Effects on Treatment and Mental Ability on Achievement and Science Process Skills in Biology Practical

The results of this study indicated that there was significant interaction of treatment and mental ability on students' achievement and science process skills. This implies that the effects of the strategies on achievement and science process skills were sensitive to mental ability. Gayford Problem-Solving Heuristics and Modified Lecture Method were most beneficial to the high mental ability students. The high ability students remained consistently in the high ability level after their exposure to the treatment. This was however different with students in Bio Problem-Solving Instructional Strategy. The medium and low ability students in Bio Problem-Solving Instructional Strategy measured up with those in the high ability group and did better in academic performance. Medium and low mental ability students greatly benefited from the Bio Problem-Solving Instructional Strategy over other ability groups in the Gayford Problem-Solving Heuristics and the control which is contrary to many research findings where the high ability students have always proved superior over others.

The advantage the students in Bio Problem-Solving Instructional Strategy had over the other two groups could be due to the involvement of the students in the production of instructional materials which they used for practical activities. Also, the high performance of the medium and low ability groups who showed greater transfer of learning could be as a result of the effectiveness of the teaching strategy which motivated them. These findings run contrary to the submission of Olagunju and Chukwuka (2008) that high mental ability students are usually better equipped intellectually to cope with the processes and mental stress which is involved in problem solving. However, the findings of this study agrees with the submission of Adesoji, (2008); Okafor (1999); Haung (1995) and Felder (1994) who observed that students of varying ability level can be motivated to learn and be helped to improve their thinking abilities when instructional materials and appropriate teaching strategies are employed by the teacher during laboratory teaching. Thus the high, medium and low mental ability students can gain maximally from the teaching learning process.

4.8.5 Interaction Effects of Treatment and Gender on Students' Achievement and Science Process Skills in Biology Practical

The results showed that there was no significant interaction effect of treatment and gender on students' achievement and science process skills in Biology Practical. This implies that the interaction of treatments and gender did not significantly influence the students' academic achievement. The problem solving instructional strategies which are activity oriented as well as being step by step systematic problem solving enabled the students to solve the problems. Therefore, what contributed to students' achievement and the acquisition of science process skills in Biology are the instructional strategies employed in the teaching learning transaction.

4.8.6 Interaction Effects of Treatment, Mental Ability and Gender on Students' Achievement and Science Process Skills in Biology Practical

The results showed that there was no significant interaction effect of treatment, mental ability and gender on students' achievement and science process skills in Biology Practical. This means that the combination of treatment, mental ability and gender are not associated with the students' performance in Biology Practical.

Also, the interactions of the three variables were not strong enough to make any significant contributions towards improving students' achievement and science process skills. This lack of interaction effects showed the efficacy of the Problem Solving Strategy, that is, the main effect is valid for the students in the study. It also showed that the strategy could be used for teaching and learning irrespective of the students' gender (male or female) and their mental ability status (high, medium or low). This result supports the findings of Oduwaiye (2009) who found the interaction of treatment, gender and ability levels of students not to be significant for achievement.

CHAPTER FIVE

SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

This chapter presents the summary of findings, educational implications of the results and recommendations. Also presented are the limitations of the study and suggestions for further study.

5.1 Summary of Findings

In this study, seven null hypotheses were stated and tested at 0 .05 level of significance. The findings of the study are summarized as follows.

1. There was a significant difference in the achievement and science process skills mean scores of students exposed to the Bio Problem-Solving Instructional Strategy, Gayford Problem-Solving Heuristics and Modified Lecture Method. The mean scores showed a gain in the scores of the students in the post test over their pretest scores. The result shows that the mean differences between the students exposed to Bio Problem-solving Instructional Strategy (BioPSIS) and Gayford Problem-Solving Heuristics (GPSH)was not significant. Students in Bio Problem Solving Instructional Strategy had the highest mean score in science process skills in Biology Practical.
2. There was no significant main effect of mental ability on students' achievement. However there was a significant main effect of mental ability on students' science process skills in Biology Practical.
3. There was no significant main effect of gender on students' achievement and science process skills in Biology Practical.
4. There was a significant interaction effect of treatment and mental ability on students' achievement and science process skills in Biology Practical. Medium

ability students in Bio Problem-Solving Instructional Strategy had the highest mean score while high mental ability students benefited maximally from Gayford Problem-Solving Heuristics and Modified Lecture Method. However, for medium and low ability students, Bio Problem-Solving Instructional Strategy appeared to be their best method.

5. There was no significant interaction effect of treatment and gender on students' achievement and science process skills in Biology Practical.
6. There was no significant interaction effect of mental ability and gender on students' achievement and science process skills in Biology Practical.
7. There was no significant interaction effect of treatment, mental ability and gender on students' achievement and science process skills in Biology Practical.

5.2 Implications of Findings and Recommendations

Findings of this study showed that the two problem solving instructional strategies, (Bio Problem-Solving Instructional Strategy and Gayford Problem-Solving Heuristics) had positive effects in students' achievements and science process skills in Biology Practical over the modified lecture method .The instructional strategies are activity oriented which encouraged student-teacher, student-student, and student-materials interaction. They emphasized student centered instructional paradigm. This is in line with Von Seekar and Lissitz (1999) who concluded that the student-centered approach to learning "engages students socially, in interactive scientific inquiry and facilitate life-long learning". These strategies being student-centered encourage students to be responsible for what they learnt which invariably helped them to be more reflective and critical in their thinking when compared with the modified lecture method which emphasized teacher activity over students' involvement. The modified lecture method was teacher-centered, teacher dominated the class lessons and students were not given the opportunity to make scientific exploration on their own but depended on the facts given by the teacher, hence their poor performance as recorded in the study.

Findings of this study have therefore shown that when appropriate strategies such as problem solving are employed in teaching science concepts, students improve considerably in achievement and science process skills. The low mean achievement and science process skills scores of student in the Modified Lecture Method suggests that teachers should respond to the call made by the National Science Education Standards (1996) for a pedagogical shift from teacher-centered to a student-centered instructional strategy. Student-centred instruction can enable students broaden their intellectual development and critical thinking instead of memorization of facts which are later regurgitated at examination.

The influence of mental ability has a vital implication on students' achievement and science process skills in Biology Practical. The improvement in academic performance of medium and low ability students in the Bio problem-Solving Instructional Strategy showed that there was a greater transfer of learning exhibited by them. Besides, the strategy is a "catalyst" for medium and low ability students to solve practical Biology problems. In line with the above findings, teachers should take into consideration the individual differences of their students as this will enable them assess the level of students' cognitive development and formulate teaching strategies that will be most appropriate in dealing with low and medium ability groups in resolving their problem solving difficulties.

Another vital implication of this study is the effect of gender on student's achievement and science process skills. This study showed that there was no significant main effect of gender on achievement and science process skills. This implies that the problem solving strategy had about an equal effect on student of both sexes. Therefore to give students of both sexes equal chances in achievement and in the development of science process skills, authentic laboratory work and teaching strategies which are capable of reducing gender-gap in students' performances should be employed by teachers. The female students in particular should be encouraged by teachers to be involved in meaningful laboratory activities.

5 .3 Recommendations

Following the findings of this study, the following recommendations are made:

1. The importance of problem solving has been emphasized and found to be effective in helping students develop both conceptual scientific knowledge and procedural knowledge of how to solve problems. In the light of this, Faculties of Education and Colleges of Education should design problem solving programmes for teacher- trainees where they can be exposed to the rudiments of problem solving .The training programme should focus on the concepts and objectives of problem solving, methods of instructional production, instructional methodologies and evaluation techniques in problem solving. Similarly, both state and federal ministries of education as well as professional organisation such as Science Teachers' Association of Nigeria should organize seminars and workshops on regular bases for teachers on problem solving strategies in Biology and other science subjects.
2. Science Teachers should identify their students' mental ability levels by administering mental ability test like the ACER test. Thereafter, teachers should note their students' individual differences during classroom transactions and formulate teaching strategies such as the Problem Solving Instructional Strategies to deal with medium and low mental ability groups as this has been found to be effective for improved learning outcomes.
3. Gender differences in academic performance should be addressed by teachers by adopting teaching strategies such as problem solving strategy that has been found to be effective for both sexes. Using appropriate instructional strategies reduces gender-gap in students' achievement. Teachers have a tremendous role to play in encouraging both male and female student to be actively engaged in problem solving activities.
4. Biology text-books should be addressed to Problem Solving Strategies. The researcher therefore recommends that Biology text-books produced for teachers and students should be problem solving oriented.
6. The government should provide enough funds to equip science laboratory. These funds should be judiciously used in the provision of instructional materials for use by teachers and students in preparing science lessons. Also, the teachers should be involved in improvising materials to supplement those provided by the school.

Conclusion

The results of the study have shown that the use of learner-centered instructional strategies involving Bio problem solving instructional strategy and Gayford Problem Solving Heuristics are more effective in promoting students' achievements and science process skills acquisition than the modified lecture method (conventional method), where teachers still dominate the classroom and laboratory transaction. This study therefore serves as part of the various efforts employed by researchers and educators to break away from teacher-centered instructional strategies (modified lecture method) to a more functional, result-oriented strategy which make the learner actively involved in learning by "doing". This in essence, is an important goal in science education. The results also revealed that the two experimental strategies improved students' achievements and science process skills effectively irrespective of their sexes. Furthermore, learners were able to identify problems and set up modalities to solve them and finally draw up realistic conclusions on the practical activities.

Mental ability was found to influence students' academic performance. Medium and low mental ability students greatly benefited from the Bio Problem-Solving Instructional Strategy over other ability groups in the Gayford Problem-Solving Heuristics and the control which is contrary to many research findings where the high ability students have always proved superior over others. It is therefore important to emphasize again that for students' enhanced performance in achievement and science process skills acquisition, appropriate teaching strategies which are learner-centered should be employed as they have been found to help students of varying ability levels particularly the medium and low ability students. In addition, the use of materials produced by the students helped them to gain better understanding of the concepts taught and enhanced their level of acquisition of science process skills. Therefore, teachers should employ problem-solving instructional strategy in biology practical lessons.

Limitations of the study

This study was faced with some constraints which limited the generalization of the results of the study. These include:

Large class sizes in some schools affected classroom management during the laboratory sessions.

Suggestions for further Research

The following suggestions are made for further research

1. Other moderating variables such as cognitive style and attitude could be incorporated in the study using the Bio Problem-Solving Instructional Strategy.
2. Further research could be carried out using the Bio Problem Solving Model with other problem solving models to ascertain the effectiveness of the model over others.
3. The two problem solving heuristics could also be used in teaching difficult concepts such as ecology and heredity in Biology and in other science subjects.

REFERENCES

Abdullahi, T.J. 2002. The Relative Effectiveness of Experimentation and Problem Solving Approaches on Students' Achievement and Attitude to Senior Secondary School Biology. M Ed Project. Department of Teacher Education. University of Ibadan. xiv + 121pp

Abdullah, F.A.P.B. 2006. The Pattern of Physics Problem-solving from the Perspective of Metacognition. Mphil in Educational Research, University of Cambridge.

Abimbade, A. 1987. Effects of the Use of Electronic Calculator on Outcomes of Mathematics Instruction. PhD Thesis. Department of Teacher Education. University of Ibadan. xxii +385pp

Abiona, O.F. 2008. The Impact of Three Life-Skill Strategies on Students' Environmental Learning Outcomes in Sewage Disposal and Water Treatment in Biology. PhD Thesis. Department of Teacher Education. University of Ibadan. xii +243pp

Abraham,M.R. 1997. Research Matters-to the Science Teacher. Retrieved September 21, 2002, from htt://www.educ.sfu.ca/narstsite/ esearch/cycle.htm http://www.educ.sfu.ca/narstsite/research/cycle.htm

Adane, L.and Adams,A. 2011. Relevance and Safety of Chemistry Laboratory Experiments from Students' Perspective: a Case Study at Jimma University, Southwestern Ethopia. *Educational Research* 2.12:1749-1758.

Adegoke, A.I. 2000. Gender Differences in Acquisition of Science Practical Skills. M.Ed Project, University of Ado-Ekiti, Nigeria.

Adekunle, M.O. 2005. Problem Solving and Concept Mapping Strategies as Determinants of Students' Achievement and Attitudes to Some Environmental Education Concepts in Social Science. PhD. Thesis. Department of Teacher Education. University of Ibadan. xix +263pp

Adeoye, F.A. 2000. Assessment Procedure, Cognitive Style and Gender as Determinants of Students' Performance in Hierarchical Cognitive Tasks in Physics. PhD. Thesis. Department of Teacher Education. University of Ibadan.

Adesemowo, P. O. 2005. Premium on Affective Education: Panacra for Scholastic Malfunctioning and Aberration. 34th Inaugural Lecture, Olabisi Onabanjo University, Ago-Iwoye: OOU Press.

Adesoji, F.A. 2002. "Female Participation in Science, Mathematics and Technology Education". Paper presented at the monthly lecture of WORDOC, University of Ibadan, Ibadan.

Adesoji, F.A. 1991. A comparative Analysis of Problem Solving and Self–Learning Technique in Teaching Electrolysis. PhD Thesis. Obafemi Awolowo University, Ile- Ife. xxvi + 230pp

____________2008. Students' Ability Levels and Effectiveness of Problem-Solving Instructional Strategy. *Journal of Social Science* 17.1: 5-8.

Adewale, J.G. 2002. Modern Trends in Physics Teaching at the Secondary School Level. In Ayodele, S.O. (2002) *Teaching Strategies for Nigerian Secondary Schools*, Ibadan: Powerhouse Publications.

Afolabi, F. and Audu, B. 2007. Towards a Scientific Literate Public Education for Sustainable National Development. *Journal of Research in Education*, 4.2:11-14

__________, Oniyide, S.M. and Audu, B. 2008. Effects of using Music as an Alternative Strategy Inculcating Scientific Process Skills on Primary School Pupils. *Journal of Physical Sciences* 4.4:158-161

Agarkar, S.C. 1998. Relevant Laboratory Programmes for Secondary Schools-problem and Solutions. *School Science*, 33.1.

Agbeyewa, J.O. 2002. Analysis of Students' Problem Solving in Physics, Numerical Test, Utilization of Three Problem Solving Model. *Journal of the Curriculum Studies*. 2.1:212-219.

Agbowuro, C. 2008. The Effects of Metacognition on the Meaningful Learning of some Biological Concepts in Secondary Schools in Plateau State. *Proceedings of the 49th Science Teachers' Association of Nigeria Annual Conference.*

Agommuoh, P.C. and Nzewi, U.M. 2003. Effects of Videotaped Instruction on Secondary School Students' Achievement in Physics. *Journal of the Science Teachers' Association of Nigeria*, 38, 1 and 2:88-92.

Ajewole, G. A. 2003. Teaching Terrestrial Habitat in Biology to Students in African Secondary Schools for Sustainable Development. *Science Teachers' Association of Nigeria, 43rd Annual Conference Proceedings (pp 23-28) Port Harcourt Heinemann Educational Books.*

Ajiboye, J.O. 1996. A Self-learning Programme, the Modified Lecture Method and Students' Cognitive and Affective Outcomes in Some Population Education Concepts. PhD. Thesis. Department of Teacher Education. University of Ibadan. xxiv +176pp

Akale, M.A.C.and Usman, I. 1993. Effects of Practical Activities on Achievement in Integrated Science among Junior Secondary School Students in Kaduna State. *Journal of Science Teachers Association of Nigeria.* 28(1and2) 102-108.

_________. 2006. *Teacher Preparation for National Education Reform.* A Lead Paper Presented During the 4th Annual Conference of the Federal College of Education (Tech) Bichi 3rd – 6th July.

Akinbobola, A.O and Afolabi, F. 2009. Constructivist Practices through Guided Discovery Approach: the Effect on Students' Cognitive Achievements in Nigerian Secondary School Physics. *Bulgarian Journal of Science and Educational Policy* 3.2:233-252.

______________ . 2010. Analysis of Science Process Skills in West African Senior Secondary School Certificate Physics Practical Examinations in Nigeria. *American-Eurasian Journal of Scientific Research* 5.4:234-240.

Akubuilo, D.U. 1995. The Effects of Two Forms of Instructional Treatments on Process Skills Acquisition of Secondary School Students in Ecology. *Nigerian Journal of Research and Production.* 5.1:19-26.

_____________. 2004. The effects of Problem Solving Instructional Strategies on Students' Achievement and Retention in Biology with Respect to Location in Enugu State. *Journal of Science Teachers' Association of Nigeria* 39. 1. 2: 93-99.

Alberta Learning, 2004. Focus on Inquiry. A Teacher's Guide to Implementing Inquiry-base Learning.

Aktamus, H. and Ergin, O. 2007. Investigating the Relationship between Science Process Skill and Scientific Creativity. Hacettepe Universtesi Egitim Fakultesi Dergisi 33, 11-23

Alridge, B. 1992. Project on Scope, Sequence and Coordination: A New Synthesis for Improving Science Education. *Journal of Science Education and Technology*. 1: 13-21.

Anderson, J.R. 1980. *Cognitive Psychology and its Implications.* New York: Freeman.

Ango, M. L. 1992. Need Science Process Skills as Foundation for effective Technology Education for National Development. In P. O. Awotunde (Ed.), Issues in

Technology Education for National Development. Jos: *National Association of Teachers of Technology*, 1: 92-104.

Ashmore, A.D. Frazer, M.J. and Casey, M. 1979. Problem solving and Problem Solving Networks in Chemistry. *Journal of Chemical Education* 56.G: 377-379.

Ausubel, D.P. 1968: Educational *Psychology: A cognitive view"*. New York: Holt Rhine hart and Winston Inc.

Awodi, S. 1984. A Comparative Study of Teaching Science (Biology) as Inquiry Versus Traditional Didactic Approach in Nigerian Secondary Schools. *University Microfilms International*. Ann Arhor, Michigan.

Ayogu, Z. U. 2007. Challenges of Science, Technology and Mathematics (STM) Education, Policy Implementation in Nigerian Schools in the Science Teacher Today. *A Journal of School of Science, Federal College of Education, Eha – Anuful* 4 . 1.

Barrett, G. V., and Depinet, R.L. 1991. *A Reconsideration of Testing for Competence.*

Bhaskar, P., and Simon, H.A. 1977. Problem Solving in Mathematically Rich Domains. An example from engineering thermodynamics. *Cognitive Science*, 1, 193-215.

Bilesanmi-Awoderu, J.B. 2002. The Status of Biology Practical Skills' Acquisition Among Nigerian Secondary School Seniors in Ogun State. *African Journal of Educational Research* 8.1. 2: 1-7.

Bransford, J. and Stein, B. 1984. The IDEAL Problem Solver: *A guide for improving thinking, learning, and creativity:* New York: W.H. Freeman.

Bringing Information to Decision Makers for Global Effectiveness (BRIDGE) 2005. *Women of our world.* Population Reference Bureau, World Population Data Sheet, UN, World.

Brotherton,P.N. and Preece, N.F.W 1996. Teaching Science Process Skills. *International Journal of Science Education.*18.1: 65-74.

Brooks, J.G. and Brooks, M.G. 1993. The Case for Constructivist Classroom. Alexandria, Virginia: *Association for Supervision and Curriculum Development.*

Butler, D. 2000. Gender, Girls and Computer Technology. What is Status Now? Clearing House 4:225-230

.

Cambell, R.I. 1979. A Comparative Study of the Effectiveness of Process Skills of Reading, Comprehensive of Pre- service and in-service Elementary School Teachers. *Journal of Research in Science Teaching* 176.2:123-127.

Carpi, A. and Egger, E. 2009. The Process Science Vision Learning Vol POS 2.8 Retrieved April 14 2012 from http:/www.visionlearning.com/libary/module-viewer.php.mid=176.

Carroll, J.B. I993. Human Cognitive Abilities: A Survey of Factor-Analytic Studies. 828pages

Cavallo, A.M.L. 1996. Meaningful Learning Reasoning Ability and Students Understanding and Problem Solving of Topics in Genetics. *Journal of Research in Science Teaching* 33.6: 625-656.

Chang, C. and Barufaldi, J.P. 1999. The Use of a Problem-Solving-Based Instructional Model in Initiating Change in Students' Achievement and Alternative Frameworks. *International Journal of Science EDEC*. 21.4: 373-388.

Conte, M. 2000. Women Last. *Messenger of St Anthony* 24-25.

Cossa, E.F.R. 2007. A case study of Practical Work in a Cell Biology Course. Ph.D Thesis. Eduardo Mondlane, University in Mozambique.

Darwin, C. 2004. *The decent of man*. New York: Penguin Putnam Inc. (original work published 1979).

Doolittle, P.E., and Camp, W.G. 2003. Constructivism as a Theoretical Foundation for Inquiry Based Pedagogy in Agricultural Education. *Proceedings of the 30th National Agricultural Education Research Conference. (National Agricultural Education Research Conference*, CD-ROM, December 10, 2003 release).

Drayton, B., and Falk, J.K. 2001. Tell-tale Signs of the Inquiry-oriented Classroom. National Agricultural School Science Project Bulletin, 85.623: 23-24.

Duyilemi, A.N. 1997. The JETS Programmes as an Intervention Strategy in Enhancing Scientific and Technological Literacy among Nigerian Senior School Students. PhD. Thesis. Department of Teacher Education. University of Ibadan. xvii +195pp

Dyer, J.E. and Osborne, E.W. 1996. Effects of Teaching Approach on Problem-solving Ability of Agricultural Education Students with Varying Learning Styles. *Journal of Agricultural Education*, 37.4: 36-43.

Ebenezer, J.V., and Connor. 1998. *Learning to teach science:* A model for the 21st Century. 140-141.

Edelson, D.C, Gordin, D.N and Pea, R.D. 1999. Addressing the Challenges of Inquiry-Based Learning through Technology and Curriculum Design. *The Journal of the Learning Sciences* 8 . 3 . 4 : 391-450.

Edward, M.C and Parr, B. 2004. Inquiry-Based Instruction in Secondary Agricultural Education: Problem-Solving – An Old Friend Revisited. *Journal of Agricultural Education*. 45: 4.

Ehikhamenor E. A. 2003. School Location, Availability and Utilization of Resources as Correlates of Students' Academic Achievement in Biology in Secondary Schools in Ibadan. MEd. Project. Department of Teacher Education. University of Ibadan. ix + 93pp.

Emeke, E. A. and Adegoke, A. B. 2006. Effect of Indirect and Direct Teacher Influence on Dependent-Prone Students Learning Outcomes in Geometry. *Journal of Humanities* 1: 97-105.

Erinosho, S.Y. 1994. *Girls and Science Education in Nigeria*. Ijebu-Ode. Universal Business Centre.

Fajola, O.O. 2000. Effects of Three Models of Computer Based Instructional Strategies of Students' Learning Outcomes in Biology. PhD. Thesis. University of Ibadan. xiv +135pp

Falaye, F.V. 2000. The Interaction Effects of Ability and Home Environment on Secobdary School Students' Achievement in Geography. *African Journal of Education Research*, 6.12:35-40.

Federal Republic of Nigeria 2004. *National Policy in Education.* Lagos: NERDC Press.

Federal Republic of Nigeria. 1998. *National Policy on Education.* Lagos: Federal Ministry of Education.

Felder, R.M. 1994. *Gender Differences in Students' Performance and Attitudes. A Longitudinal Study of Achievement and Retention. North Carolina State University (NCSU) Raleigh Report* No. 94 A.

Foriska, T.J. 1992. *Breaking from Tradition: Using Learning Styles to Teach How to Learn. Schools in the Middle* 2.1: 14-16.

Gagne, R.M. 1962. *The Conditions of Learning*. New York: Holt, Rinehart and Wiston.

__________.1965. *The Conditions of Learning*. New York: Holt, Rinehart and Wiston.

___________.1968. *Learning Hierarchies*. Educational Psychologists 6.1.3-6

Gagne, R.M. 1980. *The Conditions of Learning*. New York: Holt, Rinehart and Wiston.

___________, and Briggs, L. 1976. Principles of Instructional Design, 2nd Ed; New York: Holt, Rinehart and Wiston, 55-79

Gagne, R.M. Briggs, L and Wager, W. 1992. *Principles of Instructional Design*, Fort Worth: HBJ College Publishers.

Galileo Educational Network, 2004. What is Inquiry? Inquiry and ICT. Retrieved July 12, 2004.from http/www Galileo.org/inquiry- what html.

Garofalo ,J. and Lester, F. 1985. Metacognition, cognitive monitoring, and mathematical performance. *Journal of Research in mathematics education*, 16.3: 163-76.

Gayford, C. 1989. A Contribution to a Methodology for Teaching and Assessment of Group Problem Solving in Biology Among 15 years old Pupils, *Journal of Biological Education*.

Geek, 2012. What are Science Process Skills. Retrieved on April 14, 2012 from www.wisegeek.com/what-are-science-p—

George Lucas Educational Foundation, (GLEF) 2001. *Project based learning research.* Edutopia. Retrieved July 12, 2004 from http://ww.glef.org/php/article. php?id=Art-887

Gerber, B.L., Marek, E.A. and Cavallo, A.M.L. 1997. *Relationships among informal learning environments, teaching procedures and scientific reasoning ability.* Paper presented at the 1997 annual meting of the National Association for Research in Science Teaching Oak Brook, IL, March 21-24, 1997.

Gott, R. and Duggan,S. (1995). Investigative Work in the Science Curriculum. Buckingham: Open University Press.

Haung, J.C. 1995. The Effect of Feedback on Achievement and Attitudes during Computer-Based Cooperative Condition. Conference Proceedings: Association for Educational Communications and Technology (CAECT) Anaheim, CA. 9.

Haury, D. L.1993. Teaching Science through Inquiry. ERIC/CSMEE Digest. *Eric Clearinghouse for Science and Mathematics and Environmental Education* Columbus OH.

Henderson, J and Lally, V. 1988. Problem Solving and Controversial Issues in Biotechnology. *Journals of Biological Education.*

Hiebert, J., Caarpenter, T.P., Fennema, E., Fuson, K., Human, P., Murray, H., Olivier, A., and Wesarne, D. 1996. Problem Solving as a Basis for Reform in Curriculum and Instruction: The case of mathematics. *Educational Researcher,* 25.4: 12-21.

Hinrichsen, J., Jarrett, D. and Peixollo, K, 1999. *Science Inquiry for the Classroom*-A Literature Review.

Hofstein, A., and Lunetta, V.N. 1982. The Role of Laboratory in Science Teaching: Neglected aspects of research. *Review of Educational Research,* 52.2: 201-217.

Hudson, D. 1990. A Critical Look at Practical Work in Science. *School Science Review* 71.256:33-40.

Ibe. E. and Nwosu A. A. 2003. Effects of Guided-inquiry and Demonstration Science Process Skills Acquisition among Secondary School Biology Students. *Journal of Science Teachers Association of Nigeria* 38. 1.2: 58-63.

________ 2006. Breaking Gender Barriers on Achievement in STME using Hands-On, Minds-On Science. Implication for Supply of Resources. Proceedings of 47th Science Teachers' Association Annual Conference, 211-214.

Ige, T.A. 1998. Concept Mapping and Problem Solving Teaching Strategies as Determinants of Learning Outcomes in Secondary School Ecology in Nigeria. PhD Thesis.Department of Teacher Education. University of Ibadan. xvii +306pp

______. 1999. Improving Practical Assessment in Biology by Using Practical Skills Assessment Inventory. *African Journal of Educational Research,* 5(2), 34 – 44.

_______. 2003. "A Problem Solving Model for Bridging the Gap between Theory and Practice in Science Teaching." *African Journal of Educational Research* 9. 1. 2: 147-155

_______.2001. Concept Mapping and Problem Solving Teaching Strategies as Determinants of Achievement in Secondary School Ecology. *Ibadan Journal of Educational Studies.* 1.1: 290-301.

Ikitde, G.A. 1994. *Fostering Experimental Proficiency of Students in Biology Through Problem Solving Approaches.* PhD. Thesis. Department of Teacher Education. University of Ibadan. xxvi +358pp

______2004. Fostering Understanding of Basic Genetics Concepts among Secondary School Students through the use of Practical Approach. *Journal of Science Teachers Association of Nigeria* 39. 1.2: 55-59.

InceAka, E.,Guven, E. And Aydogdu, M. 2010. Effects of Problem Solving Method on Science Process Skill and Academic Achievement. Journal of Turkish Science Education 7.4:13-35. Retrieved 25/10/2012 on http://www.tused.org

Inyang, N.E.U. and Ekpenyong , H.E. 2000. Influence of Ability and Gender Groupings on Senior Secondary School Chemistry Students' Achievement in the Concepts of Redox Reactions. *Journal of Science Teachers Association of Nigeria* 1.2:36-42.

Isa, H. 2005. Gender In balance in Access to Science Education: Implications for Production of Female Science Teachers. *Journal of Science Teachers Association of Nigeria* 40.1.2 : 45-52.

Johnson, M.A., and Lawson, A.E. 1998. "What are the Relative Effects of Reasoning Ability and Prior Knowledge on Biology Achievement in Expository and Inquiry Classes?" *Journal of Research in Science Teaching* 35.1: 89-103.

Johnson, P.D. 2002. Effects of Greeno and Mettes et al in Problem Solving Models on Students' Achievement in Physics. *Journal of the Science Teachers' Association of Nigeri*, 37. 1 . 2: 39-43.

Jonassen, D. H. 2000. *Towards a Design Theory of Problem Solving Educational Technology: Research and Development* 48. 4: 63-85.

Kanu, O. 1993. Effects of Two Instructional Strategies on Students' Learning Outcomes and Perception of Classroom Environment. PhD. Thesis University of Ibadan.

Kickbusch, K. 1996. *Teaching for understanding Educating Students for performance*. Education Issues Series.

Kirkley, J. 2003. Principles for Teaching Problem Solving PLATO Learning Inc. 2003.

Kolodner, J.L. 1993. *Case- Based Reasoning*. San Mateo, CA: Morgan Kaufman

Lancelot, W.H.1944. *Permanent learning*. New York: John Wiley and Sons, Inc.

Lavoie, D.R. 1992. The Development, Theory and Application of Cognitive-Network Model of Prediction Problem Solving in Biology. *Journal of Research in Science Teaching* 30: 42-45.

Lee,L.K.W; Goh, N.K; Chia, L.S.1996.Teaching Problem Solving.Views of Science teachers in Singapore Primary School. A Paper Presented at the Joint Conference of the Educational Research Association, Singapore and the Australian Association for Research in Education. 1-11.

Lock, R. 1992. "Gender and Practical Skill Performance in Science". *Journal of Research in Science Teaching and Research in Science* xxix 3:227-241.

Maduabum, M. A. 2006. Stratgies for Improving the Access of Girls and Women in Science,Technology and Mathmatics (STM), University of Education in Nigeria, Ebonyi. *Journal of Science Education* 1. 1 : 1-12.

Lucy, E. and Nkoyo, I. 2000. "The Sanctity of woman in Science and Technology. Problems and prospects". *Journal of Women in Academics* 1.1: 90-99.

Mari, J. S. 2001. The Effect of Science Process Based Instruction on Formal Reasoning. Ph.D Thesis. Department of Education. Ahmadu Bello University, Zaria.

Mayer, R.E. 1992. Thinking Problem-solving Cognition (2nd ed.). New York: Freeman.

Mbanefoh, N. 1997 "Women Education". In Phillips, A.O. and Tunji, T.S. (Eds) Ibadan Nigeria in 2010. Nigerian Institute of Social and Economic Research, (Niser).

Mettes, C.T.C; Pilot, A. and Ressink, H.J. 1981. Lin-king Factual and Procedural Knowledge in Solving Science Problems. A case study in thermodynamics course. *Instructional Science.* 10: 333-361.

Millar, R. 2004. *The Role of Practical Work in the Teaching and Learning of Science*. Paper Prepared for a meeting:- High School Laboratory: Role and Vision, *National Academy of Science.* 2.

Mkpa, M.A. 2001. *Promoting Functional Education in the new millennium.* A keynote address presented at the millennium faculty week of faculty of education, E.SUT held on 13th-17th August.

Morribend, B. 2004. Gender and Academic Ability as Determinant of students' Affective and Cognitive Achievement in Environmental Education. *Journal of Environmental Value Education* 98.2:10-25.

Musheno, B.V., and Lawson, A.E. 1999. Effects of Learning Cycle and Traditional Text on Comprehension of Science Concepts by Students at Differing Reasoning Levels. *Journal of Research in Science Teaching*, 36.1: 23-37.

Myers, B.E and Dyer, J.E. 2006. Effects of Investigative Laboratory Instruction on Content Knowledge and Science Process Skill Achievement across Learning Styles. *Journal of Agricultural Education* 47.4:52-63.

National Research Council 1996. National Science Education Standards. Washington, DC: National Academy Press. Retrieved Nov. 16, 2000, from http://www,nap.edu/readingroom/books/nses/html/notice.html

National Science Education Standards 1996. Washington, DC: National Academy Press. Retrieved Nov. 16, 2000, from http://www,nap.edu/readingroom/books/ nses/html/notice.html

Ndioho, O. F. 2007. Effects of Constructivist Based Instructional Model on Senior Secondary School Students' Achievement in Biology. *In U. Nzewi (Ed) Conference proceedings of the 50th Science Teachers' Association of Nigeria annual conference 98-101*

Njoku, Z.C. 2006. Effect of Instruction using Gender Inclusive Science Kits on Girls' Interest, Participation and Achievement in Primary Science. *Review of Education Journal* 2:1-9.

Nneji, N.G. 1997. Understanding Teaching and Evaluating Skill Acquisition. *Journal of School of Technological Education,* Federal College of Education (Technical), Akoka. 1.1: 16-20.

Noyak, C. C. 2002. Educational Challenges for the Information Age. *Interdisciplinary Education Journal 4.1: 3-17.*

Nwagbo, C. 2006. Effects of Two Teaching Methods on the Achievement in and Attitude to Biology of Students of Different Levels of Scientific Literacy. *International Journal of Education Research. 45: 216-229.*

__________ 2008. Science, Technology and Mathematics (STM) Curriculum Development. Focus on Problems and Prospects of Biology Curriculum Delivery. *Proceedings of the 49th Science Teachers' Association of Nigeria Annual Conference.*

__________ and Chukelu, U.C 2012. Effects of Practical Activities on Students' Science Process Skills Acquisition. Retrieved on April 14, 2012 from Stanonline.org/journal/pdf/JSTAN-ch.

Nzewi, U.M and Osisioma, N.U.I. 1994. The Relationship between Formal reasoning ability, acquisition of Science process skills and science achievement. *Journal of Science Teachers Association of Nigeria* 29. 1.2 : 41-45.

________2008. Practical Approach to the Effective Teaching of Ecological Concpts for Sustainable Development. *Science Teachers' Association of Nigeria (STAN) Biology Panel Series.*

Obiekwe, C.L. (2008). Effects of Constructivist Instructional Approach on Students' Achievement and Interest in Basic Ecological Concepts in Biology. Unpublished M.Ed Thesis. Department of Science Education, University of Nigeria, Nsukka.

Obomannu, B.J. and Nbina, J.B. 2010. An Assessment of the Effects of Problem Solving Instructional Strategies on Students Achievement and Retention in Chemistry with respect to Location in Rivers State. Retrieved 10/10/2010 http://www science pub.net

Odubunmi, E. O. 2006. *Science and Technology Education in Nigeria: The Euphoria, the Frustration and the Hopes.* 21st Inaugural Lecture, Lagos State University, Lagos: Faculty of Education.

Oduwaiye, J.O.O. 2009. Impact of Computer-Assisted and Textual programmed Instructions on Pre-Service Teacher's Learning Outcomes in Some Environmental Education Concepts in Biology. PhD Thesis. Department of Teacher Education.University of Ibadan. xx +226pp

Ofoegbu, T.O. 2005. Effects of Students' Involvement in the Production of Instructional material on their academic performance in Biology. *Journal of the Science Teachers Association of Nigeria* 40.1.2: 68-73.

Ogunsola-Bandele, M.F and Lawan, F.K. 1996. Gender Related Difference in Error. Analysis of Some Nigerian High School Students in Practical Biology. In ERIC Documentary. An:Ed393698. CHN:SE058251.

Okafor, P.N. 1999. *Effects of Cooperative Learning and Conceptual Change Pedagogical Strategies on Students Achievement and Attitude towards Chemistry.* PhD. Thesis. Department of Teacher Education.University of Ibadan. xv +228pp

________.and Okeke, S.O.C. 2006. Concept Mapping as an Effective Technique for Teaching difficult concepts in Biology. *Conference proceedings of the 47th Science Teachers Association of Nigeria Annual Conference* 122.

Okebukola, P.A.O. 1984. Science Laboratory Behaviour Strategies of Students Relative to Performance and Attitude to Laboratory Work. *National Association for Research in Science Teaching* 223-231.

_______. 1992. Can Good Concept Mappers Be Good Problem Solvers in Science? *Educational Psychology* 12.2: 113-129.

Okeke, E. A.C. 2001. "Women in Science, Technology and Mathematics Education in Nigeria". *Lead Paper, 42nd Annual Conference of Science Teachers Association of Nigeria*

Okeke, S.O.C; Akusoba, E.U and Okafor, C.O.2004. Construction and Validation of an Instrument for Appraising the Level of Acquisition of Science Process skills by JSS Graduates in Anambra State Schools *Journal of Science Teachers' Association of Nigeria*, 39.1.2:100-107.

Okoye, N. S and Okechukwu, R.N 2010. Effects of Concept Mapping and Problem Solving Strategies on Achievement in Biology among Nigerian Secondary School Students.
Find articles.com/../ai-n57087918/ Retrieved March 30, 2010 from htpp:www.ajol.info//.59616

Oladokun,T. 2000. The Relative Effectiveness of Concept Mapping Analogy and Problem-solving Strategies on Students' Learning Outcomes in some Environmental Concepts in Biology. M.Ed. Department of Teacher Education, University of Ibadan. 141pp

Olagunju, A. M. 2002. Improving the Quality of Teaching and Learning of Elementary Science through a Resourceful Environment. *Nigerian Journal of Emotional Psychology and Sport Ethic* 4: 84-89.

____________ Adesoji, F. A., Iroegbu, T. O. and Ige, T. A. 2003. Innovation in Science. Teaching for the new Millenum. In Education this Millenum, Innovation in Theory and Practice. Edited by Oluremi Ayodele Bamisaye. Macmillan Publisher, Nigeria.

______________ and Ojo, T.A. (2006). Impact of Video CD and Audiocassette-Based Instructions on Secondary School Students' Environmental Knowledge in Selected Environmental Topics in Biology. *Nigeria Journal of computer Literacy* 7.1:37-51.

______________ and Chukwuka, E.U. 2008. Effects of Moral Dilemma and Problem-Solving Strategies on Students' Achievement in Conservation, Waste Management, Pollution and Overpopulation Concepts in Biology. *African Journal of Educational Research,* 12.1:55-67.

Olokun, M. 2002. Gender Inequality in Higher Education. A Remedial Approach. The Nigerian Teacher Today. *A Journal of Teacher Education,*. 10.1:134-142.

Onwioduokit, F. A, 1989. Development of Students' Laboratory Skills using three Problem-Solving Models in Practical Physics. PhD Thesis. Department of Teacher Education. University of Ibadan. xviii +

Onyegegbu, N. 2001. Provision of facilities in biology classroom. New direction and challenges. *International Journal of Education Research* 5: 70-75.

____________. 2006. Using New Technologies in Creating Excitement in Biology Laboratory Activities. *Conference proceedings of the 14th Science Teachers' Association of Nigeria annual conference 134-137.*

Oriade, T. L. 2007. An Empirical Study of the use of Instructional Materials in Biology Curriculum Implementation: A Case Study of Selected Secondary Schools in two LGA of Bauchi State. *Conference proceedings of the 49th Science Teachers' Association of Nigeria annual conference*

Orimogunje, T. 2003. The Relative Effects of 5-step Problem Solving Approach and Lecture Method on Students' Understanding of Mole Concept. *Journal of Science Teachers' Association of Nigeria* 2: 28-33.

_____________. 2008. Effects of Two Problem Solving Models in Facilitating Students' Learning Outcomes in Chemistry. *Journal of Educational Foundations and Management* 6.1:226-232.

Orji, A.B. 1998. Effects of problem solving and concept-mapping instructional strategies on students learning outcomes in physics. PhD Thesis. Department of Teacher Education. University of Ibadan. xvii +239pp

__________. 2000. Comparability of Two Problem Solving Model in Facilitating Students' Learning Outcomes in Physics. *Journal of Science Teachers' Association of Nigeria.* 3.1.2:25-30.

Orukotan, A.F. 1999. The Relative Effect of Instructional Strategies of Framing and Rehearsal on Senior Secondary School Students Learning Outcomes in Some Biology Topics. PhD. Thesis. Department of Teacher Education. University of Ibadan.xviii +266pp

Owens, R.F., Hester, J.L.,and Teale, W.H. 200. Where do you want to go today? Inquiry based learning and technology. *Reading Teacher* 55.7: 616-626.. Retrieved Dec. 20, 2002, from http://search.epnet.com/direct.asp?an=6437872 anddb=afh

Padilla, M.J., Okey, J.R., and Dillashaw, F.G. 1983. The Relationship between Science Process Skills and Formal Operational Thinking Abilities. *Journal of Research in Science Teaching* 20: 239-246.

Pinker, S. 2002. *The blank state.* New York: Penguin Putnam, Inc.

Piwuna, C.N. 2000. Gender Dimensions of Equalization of Educational Opportunities in Nigeria. P*hilosophy of Education Association of Nigeria (PEAN)* : 64-72.

Pizzini, E.L., Shephardson, D.P. and Abell, S.K. 1989. A Rational for the Development of a Problem-Solving Model of Instruction in Science Education. *Science Education,* 73: 523-534.

Popoola, A.A. 2002. Effects of Heuristic Problem Solving and Programmed Instructional Strategies on Senior Secondary School Students' Learning

Outcomes in Mathematics in Ekiti State Nigeria. PhD Thesis. Department of Teacher Education. University of Ibadan. xviii +353pp

Raimi, S.M. 2003. Gender Differences in Acquisition of Practical Skills. Unpublished Paper Presented at the 1st National Conference on Science, Technology and Mathematics Education School of Science, St Andrew's College of Education, 17th – 20th July.
Rather than for Intelligence.46:1012-1024.

Raimi, S.M and Fabiyi O.O. 2008. Science Practical Skills Teaching: A Panacea for Promoting the Acquisition of Science Practical Skills among Secondary School Students. *Journal of African Foundations and Management.* 6.1:32-43.

Reif, F; Larkin, J.H.and Brackeh, G.C. 1976. *Teaching General Learning and Problem Solving Dissertation,* University of Colorado, Denver.

Robberts, R. and Gott, R. 2003. Assessment of Biology Investigations. *Journal of Biological Education* 37. 3: 114-121.

Rufus, O.O. 2002. Effects of Academic Ability and Gender on Students' Knowledge of Environmental Concepts and Attitudes on Line Publication: www.http://naaee. org/npeel Retrieved Dec.5. 2004

Salami, M.O. 2002. Students' Mental Ability and Gender as Determinants of Achievement in Chemistry Practical. B.Ed project. University of Ado-Ekiti.

Salawu, I.O. 1999. Effects of Three Instructional Modes of Student-teachers' Performance in Selected Teaching Skills. PhD Thesis. University of Ibadan. xvii +191pp

Schiefele, U. and Csikzentmihalyi, M.C. 1995. Motivation and Ability as Factors in Mathematics Experience and Achievement. *Journal for Research in Mathematics Education* 26.2: 163-181.

Science Teachers' Association of Nigeria (STAN). 1992. *Science Teachers Handbook:* Longman Nigeria Ltd.

Shaibu, A.A.M and Mari J.S. 1999. Gender Related Difference on the Understanding of Science Process Skills Amongst Junior Secondary Schools in Nigeria. *Journal of Science Teachers' Association of Nigeria.* 34. 1. 2: 70-79.

Smilkstein, R. 2003. *We are born to learn:* Using Brain as Natural Learning Process to Create Today as Curriculum. Thousand Oaks; CA. Corwin Press, Inc.

Smith, M.U. 1991. *A view from biology.* In M.U. Smith (ed.), Toward a unified theory of problem solving. Hillsdale, NJ: Lawrence Erlbaum Associates.

Suchman, J. 1966. Developing Inquiry. Chicago Science Education Association International.

Suits, J.P. and Lagowski, J.J. 1994. Chemistry Problem solving abilities: Gender Reasoning Level and Computer Simulated Experiments. Papers presented at the Annual Meeting of the National Association for Research in Science Teaching. Anaheim, C.A. 26-29.

Szent-Gyorgi, A. 1994. *Teaching and Expanding Knowledge. Science* 146: 1278-1279.

Tobin, K. and Garnette, P. (1987) Gender-related Differences in Science Activities. *Science Education* 7.1: 91-103.

Toh, K.A.1993. Gender and Practical Tasks in Science. *Educational Research.* 35: 255-265.

Udogu E, Ifeaker A.C and Njelita, C.B. 2007. Evaluating the Level of Usage of Pedagogical Skills by Science, Technology and Mathematics Teacher in Secondary Schools for Sustainable Development. *Proceedings of the 50th Science Teachers' Association of Nigeria Annual Conference.*

Ukwungwu, J.O. 2002. Gender Difference. Study of Performance in Integrated Science; A Summary of Studies Conducted in Nigeria. *Journal of the Science Teachers' Association of Nigeria* 37.1.2: 55-59.

Umar, L. 1997. Problems and Prospects of Girl-Child Education in Nigeria. *Girl-Child development on the Plateau.* Heinemann Educational books (Nig) Plc. Ibadan Nigerian.

Umar, M.H. and Gbana, N.H. 2004. Girls Education: An investment for the Future. *Journal of Women in College of Education (JOWICE) 9: 128-135.*

UNICEF 1994. *"Progress of the Nations".* A UNICEF publication. Report on the World Conference on Education for All 1990. Jomtien, Thailand.

Von Secker, C.E., and Lissitz, R.W. 1999. Estimating the Impact of Instructional Practices on Student Achievement in Science. *Journal of Research in Science Teaching.* 36.10: 1110-1126.

Webb, 2012. What is Science as a Product and as a Process. Retrieved April 14, 2012 from http://www.ehow.com/how5781925-incorporatr-sc.pro.skill

West, S.A. 1992. "Problem Based Learning – A Viable Addition for Secondary School Science" *School Science Review* 73: 47-53.

Yoloye, E.A. 1982. *Science Education in the Nigerian Primary Schools:* A Need for Radical Aapproach, keynote Address at the 25th Anniversary Conference of Science Teachers' Association of Nigeria.

Yoloye, E. A. 2010. Science Education for Skill Acquisition, Bridging the gap between Theory and Practice. Lecture presented at the 5th National Conference of School of Science Education, Federal College of Education (Tech) Akoko, Lagos

APPENDIX I

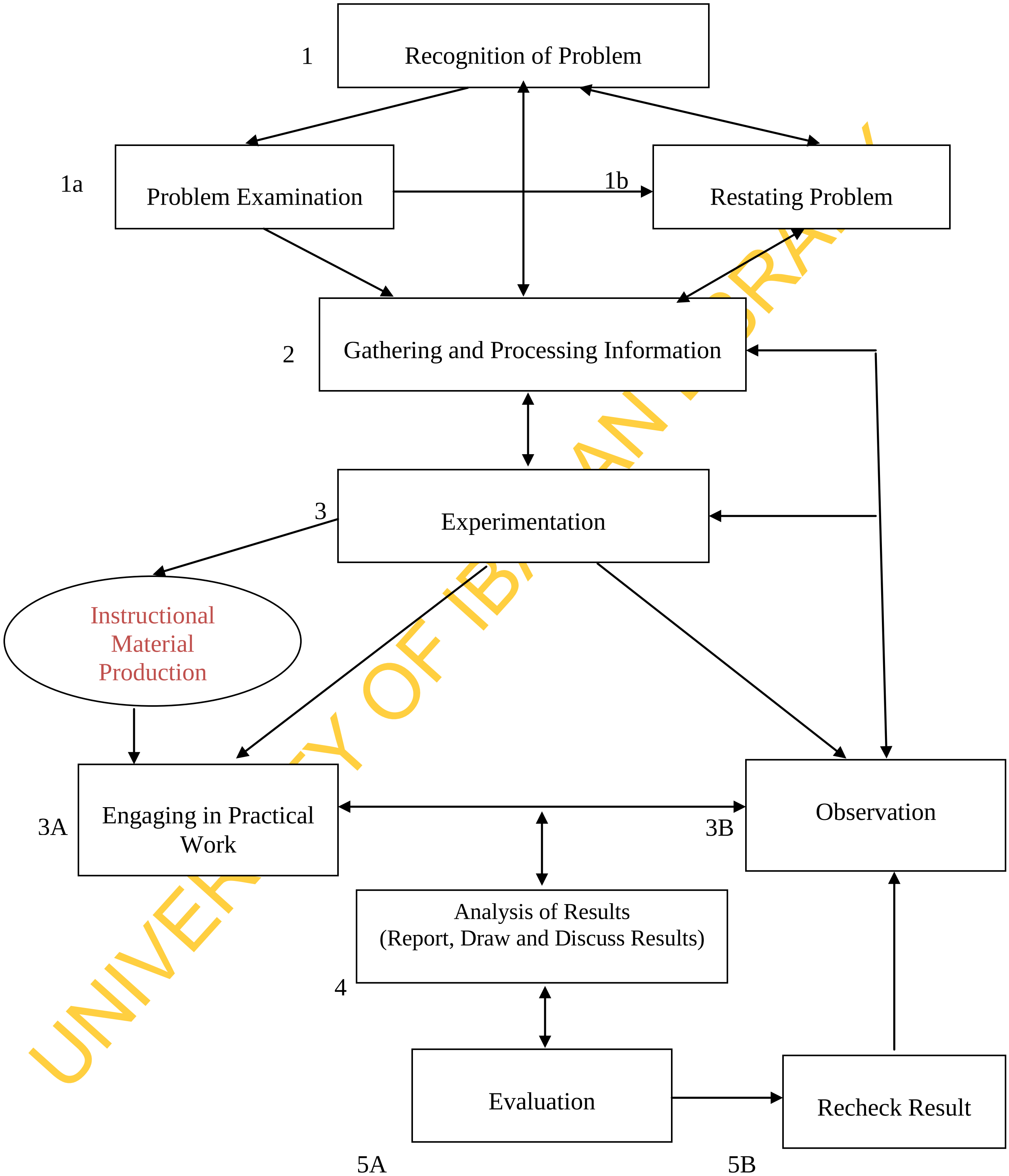


Figure 3.1: Bio Problem Solving Model (BioPSOM). **Adapted from Researcher's Experimental Problem Solving Model (1994)**

APPENDIX II

ACHIEVEMENT TEST IN PRACTICAL BIOLOGY

SECTION A

Name of School: ---

Class: ---

Sex:--

SECTION B

INSTRUCTION

Candidates are to answer all the questions in this section. Each question is followed by five options lettered A to E. Find out the correct option for each question and write your answer in the answer sheet provided.

1. The following are functions of the skeleton except
   A. Providing support for the body
   B. Protection of delicate internal organs
   C. Maintenance of the shape of the body
   D. Providing attachment for muscles
   E. Controlling growth rate in animals
2. Muscles are attached to bones by means of
   A. Ligament
   B. Cartilage
   C. Synovial membrane
   D. Tendons
   E. Connective tissue
3. The tissues below are found in plants. Which of them is not found in the stem and root of monocotyledons?
   A. Cambium
   B. Pith
   C. Xylem
   D. Cortex
   E. Pericycle

4. What happens to a young man when the biceps muscle of his arm contract? The

   A. Fore arm bends
   B. Fore arm straightens out
   C. Scapula changes position and moves towards the sternum
   D. Triceps muscle contracts as well
   E. Biceps relaxes at the same time

5. Which of the following groups of vertebrae has two branches at the end of their transverse process?

   A. Thoracic
   B. Sacral
   C. Cervical
   D. Lumbar
   E. Caudal

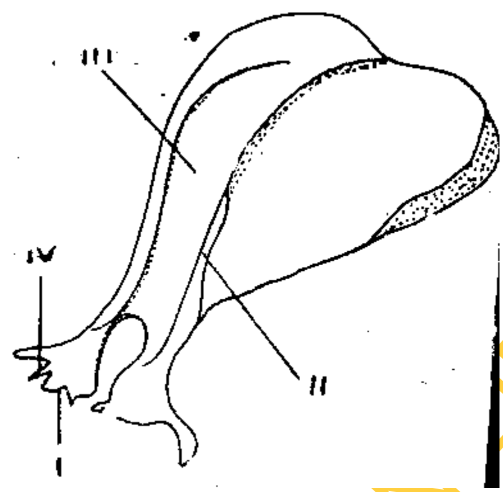
6. The xylem vessels carry out the function of transport as well as help to support plants. They are able to do this because they

   A. Are tubular
   B. Are located internally
   C. Possess rigid thick walls
   D. Constantly absorb water
   E. Cambium separates them from the phloem

7. The following are a type of exoskeleton except

   A. Cartilage
   B. Hoof
   C. Chitin
   D. Shell
   E. Nail

Use the diagram below to answer questions 10-12.



8. What function does the structure labeled II carry out?

   A. Support for the chest

   B. Passage of blood vessels

   C. Point of attachment of muscles

   D. Point of articulation with other bones

   E. Passage of nerves

9. The bone which fit into the structure marked I is

   A. Femur

   B. Radius

   C. Humerus

   D. Tibia

   E. ulna

10. The diagram illustrated in Fig 1 is located in which region of the body?

   A. Abdominal

   B. Shoulder

   C. Tail

   D. Neck

   E. Waist

11. What significant role does the vertebrarterial canal found in the cervical vertebra perform in an adult man?

A. It is a passage for the spiral cord

B. It makes forward and backward movement possible

C. Rotational movement of the head is made possible

D. Blood vessels pass through it

E. Movement in all directions is made possible easily

12. The following are features of supporting tissues in plants except

A. Rigidity

B. Turgidity

C. Flexibility

D. Hardness

E. Malleability

13. Which of these vertebrae provide articulating surfaces for the ribs?

A. Thoracic

B. Cervical

C. Caudal

D. Sacral

E. lumbar

14. The tissue which transport organic food from its site of production to all other parts of the pants is known as

A. Phloem

B. Cambium

C. Xylem

D. Epidermis

E. Cortex

15. The underlisted statements are the functions of groups of mammalian vertebrae excepts

A. Lumbar vertebrae provide attachment for the muscles found in the abdomen

B. The neck is supported by the cervical vertebrae

C. Thoracic vertebrae articulate with the ribs

D. Caudal vertebrae support the tail and provide attachment for tail muscle

E. Sacral vertebrae support the skull and allow nodding and rotating movements

16. What distinguishing feature will help you to identity the axis vertebrae

A. Very small centrum

B. Odontoid process

C. Small neural spine

D. Large transverse process

E. All of the above

17. The joint that will permit movement in all planes of directions in an animal body is

A. Hinge joint

B. Ball and socket joint

C. Pivot joint

D. Gliding joint

E. Movable joint

18. Most herbs do not attain considerable height, they are usually annuals. What probable explanation can account for this?

A. Lack of a more complex support system

B. Presence of a less efficient conducting

C. Presence of a more complex support system

D. Lack of cambium

E. They only live for one year

19. A man who stretches out his forearm to pick an apple from the table and after wards bends the forearm towards the mouth to have a bite of the apple is using the

A. Hinge joint

B. Ball and socket joint

C. Gliding joint

D. Pivot joint

E. Sliding joint

20. A number of processes come out of the centrum of a vertebra. These are designed to

A. Protect the animal from its enemies

B. Provide sufficient room for the vertebra

C. Provides position for the attachment of muscles

D. Protect the spinal cord from dangers

E. Provide articulatory factors for pelvic girdle

21. The following statements give the appropriate roles each group of the mammalian vertebrae perform except

A. Cervical vertebrae give support to the neck

B. Thoracic vertebrae articulate with the ribs

C. Sacral vertebrae support the skill and makes the nodding and rotating merits

D. Caudal vertebrae support the tail

E. Lumbar vertebrae support most of the body's weight and muscles of the abdomen are attached to them.

22. The importance of turgidity of the cells in herbaceous plants is that it

A. Provides mechanical support for the plant

B. Enables absorption of more water

C. Enables the intake of mineral salts from the soil

D. Prevents plasmolysis of the cells

E. Facilitates transpiration of excess water from the leaves.

23. Why are the vertebrae in the different body regions modified for the function required in each region? This is so because

A. The body weight is not evenly distributed along the vertebral column

B. The body weight is evenly distributed along the vertebral column

C. The number of vertebrae in each region are not the same

D. The vertebral column runs from the neck to the tail

E. Each animal has a specific number of vertebrae

24. The scapula is a flat blade and fits into the head of the humerus because of the presence of

A. Spine

B. Coracoid process

C. Glenoid cavity

D. Condyle

E. Acromion porcess

25. On windy days, plants are usually subjected to considerable amount of stress and compression without breaking or buckling, due to the presence of

A. Sclerenchyma and xylem

B. Collenchyma and phloem

C. Parenchyma and collenchyma

D. Xylem and phloem

E. Sclerenchyma and parenchyma

26. Which of the following statements about the modification of pentadactyl fore-limb is not correct?

A. Wings are modified for flying in birds

B. Flippers are modified for grasping in sharks

C. Legs are modified for walking and running in centuples

D. Arms are adapted for grasping and holding in human being

E. Flippers are modified for swimming in whales

27. The dentition of a herbivore is distinct from that of other animals due to the presence of

A. Diasterma

B. Cups on molar teeth

C. canines

D. ridges on molar teeth

E. presence of the carnassial teeth

28. Why are the incisors of herbivore regarded as open teeth

A. The teeth grow continuously.

B. There are no canine teeth.

C. There is a gap between the incisors and the premolars.

D. The incisors wear away fast.

E. All of the above.

29. What are the teeth of herbivores adapted for

A. For cropping grass and grinding plant matter.

B. For eating flesh.

C. To chop off pieces of grass.

D. To hold on to grass while resting.

E. None of the above.

30. The two lower jaw bones of the rabbit consists of how many teeth

A. 12

B. 6

C. 14

D. 7

E. 28

APPENDIX III

SCIENCE PROCESS SKILLS TEST IN TISSUES AND SUPPORTING SYSTEMS IN ANIMALS AND PLANTS

Instructions:

(a) Answer all questions in the worksheet booklet.

(b) You are advised to use sharp pencils for all your drawings. Neat, accurate drawings and observations are encouraged. This paper will last for 2 hours 30 minutes.

1. You are provided with the bones of the fore-arm/hind limb of a rabbit.

(a) Demonstrate the arrangement of the bones of the fore-arm to make a lever system showing the position of muscles attachment on the bone.

(b) What class of lever is represented in 1(a)? (1 mark)

(c) (i) Demonstrate the joint that occurs between specimen B and F.

(ii) What is the name of the joint? (1 mark)

(d) Observe Specimens A and B carefully. What are the names of the bones?

A ____

B ____ (2 marks)

(e) Make a large labelled diagram 8 to 12 cm long of the dorsal view of specimen B.

(10marks)

(f) Given the following specimens, A,B,C,D demonstrate how the bones articulate with specimen A at the

(I) anterior end

____

____

(II) posterior end

____

____

(g) Name the type of joints associated with specimens A and B at the proximal end. (2 marks)

____

(h) State ONE function of specimen A and ONE of specimen B. (1 mark).

A. ____

B. ____

(i) Name TWO structures found in green multicellular plants that are comparable to specimen A and B. (2 marks)

____

____

(j) State any TWO muscles attached to specimen B. (2 marks)

____

____

2. **Experiment**

How would you explain to J.S 3 students that some tissues in the plant stem carry out the function of conducting water from one part of the plant to another?

Experimental set-up 2 illustrates this process

Now answer these questions

2 (a). What is the aim of this investigation? (1 mark)

With a razor blade or scalpel, cut a portion of the stem and label it specimen E.

2(b). Make a large labelled drawing 8 – 10cm long of the cut surface of specimen E.

(10 marks)

(c) Name the tissue that is stained.(1 mark)

(d) State TWO functions of the stained portion. (2 marks)

(i) --

(ii) --

(e) State TWO possible effects of the absence of the stained portion in the stem of a plant. (2 marks)

(i) --

(ii) --

(f) How are the supporting tissues distributed? (1 mark)

(g) What is the effect of this form of arrangement to the stem? (1 mark)

(h) How would you describe the arrangement of the vascular bundles in monocotyledonous stem? (1 mark)

APPENDIX IV

SCIENCE PROCESS SKILLS ASSESSMENT INVENTORY

Name:

School:

Sex:

SKILL TO BE ENHANCED	CRITERIA TO BE MEASURED	SCORE		
Manipulative Skill	This involves proper handling of apparatus and the setting up of equipment as well as the preparation of materials.	2	1	0
	1. Correct arrangement of the skeletal bones of the forearm to make a lever system.			
	2. Correct position of muscle on bone as in No. 1 above			
	3. Correct demonstration of the articulation of bones with specimen A at the anterior end (A and C).			
	4. Correct demonstration of the articulation of skeletal bones with specimen A at the posterior end. (A and D)			
	5. Appropriate cut of the stem to be used.			
	6. Correct use of hand lens in observing stained portion of the stem.			
	7. Drawing skill, clarity of lines			
	8. Correct demonstration of joint between A and C			
Observational Skill	1. Ability to identify the details in a specimen e.g., Deltoid ridge			
	2. Correct identification of xylem			
	3. Correct identification of the axial skeleton on the mounted mammalian skeleton			
	4. Correct identification of the bones of the appendicular skeleton on the mounted mammalian skeleton.			
Communication Skill	This involves ability to represent findings of practical work in a logical manner with correct illustrations (drawings) showing all the details. This entails reporting, representing and discussing results.			
	1. Ability to express oneself coherently in good language.			
	2. Ability to interpret findings observed.			
	3. Ability to make correct drawing e.g (i) details emphasized in the question shown (stained portion shown in crossed lines). (ii) double lines for cut epidermis			

APPENDIX VA

A.C.E.R. HIGHER TEST

MATHEMATICS

Name-------------------------------------- **Age Now**--------------------------------------

Date of Test------------------------------ **Birthday**-------------------------------------

School ------------------------------------- **Class**---------------------------------------

This is a test to see how well you can think. It contains questions of different kinds. Some examples and practice questions will be given to show you how to answer the questions.

Example A:

Find out how the following numbers go. Write the missing numbers in the brackets

2 5 8 . 14 17 . 23 (11 and 20)

Question 1:

Find out how the following numbers go. Write the missing numbers in the brackets:

4 3 6 5 . 7 10 . (8 and 9)

Question 2:

Find out how the following numbers go. Write the missing numbers in the brackets:

1 3 5 7 . 11 . 15 (9 and 13)

Question 3:

Find out how the following numbers go. Write the missing numbers in the brackets:

26 23 20 17 14 . 8 (11 and 5)

Example B:

Find the number which should be in the square with the question mark and write it in the brackets:

3	5	7
6	8	10
9	11	?

(13)

Question 4:

In this table two numbers are missing. Find the number which should be in the square with the question mark and write it in the brackets.

2	5	9
6	.	13
11	14	?

(18)

Question 5:

Find the number which should be in the square with the question mark, and write it in the brackets

1	3	5
3	.	7
5	7	?

(9)

Question 6:

Find the number which should be in the square with the question mark, and write it in the brackets.

17	13	9
15	11	?
9	.	1

(7)

You will have 20 Minutes to do the test. Some questions are easier than others. Try each question as you come to it, but if you find any question is too hard, leave it out and come back to it later if you have time. Do not spend too much time on any one question. Try to get as many rights as possible.

DO NOT TURN THE PAGE OVER UNTIL YOU ARE TOLD.

(Published by Australian Council for Educational Research. 147 Collins Street Melboume Copy right.

1. Find out how the following numbers go. Write the missing numbers in the brackets

1 5 . 13 . 21 25 29 . ( )

2 What change should I get from ₦10 note if buy two theatre tickets at N 2.50 each ( )

3. Find the number which should be in the square with the question mark, and write it in the bracket

2	1	5
8	6	.
12	?	15

( )

4. Find out how the following numbers go. Write the missing numbers in the brackets.

19 9 18 8 . 7 16 . . (and)

5. Oliver is three times as old as his sister Pat. Their father, who is 85, is seven times as old as Pat. How old is Oliver? ( )

6. Find the number which should be in the square with the question mark, and write it in the brackets

6	10	17
8	.	19
12	16	?

( )

7. Find out how the following numbers go. Write the missing numbers in the brackets

512 256 128 64 . 16 . 4 (and)

8. Which one of the following prices for oranges is the cheapest? Tell by number

(1) 3 k each

(2) 27 per doz

(3) 5 for 12k

(4) 8 for 18k

(5) 8 for 6k ( )

9. Find the number which should be in the square with the question mark and write it in the brackets.

32	8	2
.	16	4
96	24	?

10. Find out how the following numbers go. Write the missing numbers in the bracket

87 78 76 67 - 58 54 (and)

11. The total cost of ten books bound in leather is ₦200 each book in an ordinary edition costs ₦10. How much extra do I pay on each book for the leather binding?

( )

12. Find the number which should be in the square with the question mark, and write it in the brackets

2	4	8
6	-	24
8	36	?

( )

13. John and Mary are twins whose ages together are half their mother's. Their father who is three years older than their mother is 51. How old is John? ( )

14. Find the number which should be in the square with the question mark and write it in the brackets

1	3	9
2	.	10
5	7	?

( )

15. It took me four times as long to climb a mountain 6,000 metres high as it took me to come down. I descended 6,000 metres in an hour. How many hours did it take to climb up?

( )

16. Find the number which should be in the square with the question mark, and write it in the brackets.

1	-	9
4	12	36
?	48	144

( )

17. What are two numbers whose sum is 16 such that the first divided by the second gives three? ( )

18. Find out how the following numbers go. Write the missing numbers in the brackets

0 . 8 5 3 8 . 11 ( )

19. Find the number which should be in the square with the question mark, and write it in the brackets

13	9	5
7	5	?
1	.	1

( )

20. Find out how the following numbers go. Write the missing numbers in the brackets.

4 8 7 . 13 26 . 50 (and)

21. If nine framed pictures cost N130.50 and each picture unframed only costs one third as much, how many unframed pictures could I buy for the same money?

( )

22. Find the number which should be in the square with the question mark, and write it in the bracket

2	4	6
4	.	12
8	16	?

( )

23. Find out how the following numbers go. Write the missing numbers in the brackets.

1 3 . . 81 243 729 ( )

24. I bought a number of 6k magazines and 8k exercise books which cost me (N40.60) together. How many of each did I buy ( )

25. Find out how the following numbers go. Write the missing number in the brackets.

41 35 30 36 . 21 . 20 (and)

26. A greengrocer finds that by selling his carrots at 4k per N2, he makes exactly the same profit as by selling as 3k per bunch. What is the average weight of each bunch of his carrot? ( )

27. A furniture dealer bought some chairs at N48 per dozen. In selling them he received as much as two chairs as he had paid for three chairs. What was the selling price per dozen? ( )

28. Find the number which should be in the square with the question ark and write its number in the brackets

18	3	6
2		2
9	3	?

( )

GO STRAIGHT ON WITH THE NEXT PAGE

29. I can buy 5 grams of potatoes for N20.90. How much do I pay for ½ gram?

( )

30. In a class of 48 pupils there are 8 more boys than girls. How many boys are there?

( )

31. Find the number which should be in the square with the question mark, and write it in the brackets

.	1	8
18	2	7
27	?	24

( )

32. Two new books cost N4.60 and N10.60 respectively. If I buy them second hand I only pay two thirds of the new price. How much money do I save?

( )

33. A piece of wood 35 centimeters long is to be cut in three parts, each successive part being twice as long as the previous part. What is the length of the longest part?

( )

34. A kitten is 3 days old and a puppy is 11 days old. How many days will puppy be twice as old as the kitten?

( )

35. A dairy serves mixture of two parts cream and three parts milk. How many pints of cream will it take to make 15 pints of the mixture?

( )

36. Find out how the following numbers go. Write the missing numbers in the brackets

87 74 63 54 47 . 39 . (and)

LOOK BACK OVER YOUR WORK

APPENDIX VB

A.C.E.R. HIGHER TEST

ENGLISH LANGUAGE

ML

Name-- **Age Now**--------------------------------------

(SURNAME BLOCK LETTERS)

Date of Test------------------------------------- **Birthday**--------------------------------------

School-- **Class**---

This is a test to see how well you can think. It contains questions of different kinds. Some examples and practice questions will be given to show you how to answer the questions.

EXAMPLE A. Four of the following are alike in some way. Write the numbers of the other two in the brackets at the end of the line.

(1) tea (2) coffee (3) shoes (4) cocoa (5) pencil (6) milk

(and) (shoes and pencil)

Question 1. Four of the following are alike in some way. Write the numbers of the other two in the brackets.

(1) apple (2) pear (3) potato (4) banana (5) carrot (6) orange

(potato and carrot) ($)

Question 2. Four of the following are alike in some way. Write the numbers of the other two in the brackets.

(1) door (2) window (3) coat (4) wall (5) roof (6) book

(coat and book) ($)

EXAMPLE B. TOWEL IS TO WATER AS BLOTTING PAPER is to

(1) school (2) Ink (3) writing (4) desk (5) pen (Ink)

Question 3. NEWSPAPER is to SEE as WIRELESS is to

(1) write (2) hear (3) dial (4) ear (5) deaf (hear)

EXAMPLE C. Which two of the following statements mean most nearly the same?

(1) Too many cooks spoil the broth

(2) Make hay while the sun shines

(3) A stitch in times saves nine

(4) It's a long lane that has no turning

(5) Strike while the iron is hot (2 and 5)

Question 4. Which two of the following statements means most nearly the same?

(2) A careless master makes a negligent servant

(3) To resist him that is set in authority is evil

(4) Little is done when many command

(5) When the cat is away the mice do play

(6) Where there are seven shepherds there is no flock (3 and 5)

Question 5. Which two of the following statements together prove that **"OUR DOG BIT THE POSTMAN YESTERDAY"?**

(1) Our dog is the only Alsatian in the street

(2) The postman was late yesterday

(3) The postman is in bed because an Alsatian bit him yesterday, in our street

(4) Dogs seem to dislike postmen

(5) The postman had a score leg last week (2 and 4)

You will have 15 minutes to do the test. Some questions are easier than others. Try each questions as you come to it but if you find any question is too hard, leave it out and come back to it later if you have time.

Do not spend too much time on any one question.

Try to get as many right as possible.

DO NOT TURN THE PAGE OVER UNTIL YOU ARE TOLD

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1. Four of the following are alike in some way. Write the numbers of the other two in the brackets.

   (1) table (2) chair (3) man (4) bed (5) cupboard (6) towel ( )

2. **FILTH** is to **DISEASE** as **CLEAN** is to:

   (1) dirty (2) safety (3) water (4) illness (5) health ( )

3. Four of the following are alike in some way. Write the numbers of the other two in the brackets. ($)

   (1) tube (2) artery (3) tunnel (4) string (5) wire (6) rope ( )

4. **INCH** is to **SPACE** as **SECOND** is to

   (1) Hour (2) age (3) time (4) clock (5) third ( )

5. Four of the following are alike in some way. While the numbers of the other two in the brackets.

   (1) lagoon (2) Pool (3) swamp (4) lake (5) marsh (6) pond (and)

6. **PIN** is to **HEAD NEEDLE** is to

   (1) pick (2) sew (3) eye (4) point (5) thread ( )

7. Four of the following are alike in some way. Write the numbers of the other two in the brackets.

   (1) onlooker (2) spectator (3) critic (4) eye-witness (5) author (6) bystander (and)

8. **HEAT is to ASHES as CARPENTRY** is to:

   (1) carpenter (2) sawdust (3) chisel (4) furniture (5) wood ( )

9. Four of the following are alike in some way. Write the numbers of the other two in the brackets

   (1) sponge (2) water (3) map (4) towel (5) blotting-paper (6) dirt (and)

10. Which two of the following statements mean most nearly the same?

(1) Time is a herb that cures all diseases

(2) Anticipation is better than realization

(3) To-day is worth two tomorrow

(4) To spend today is to be set back tomorrow

(5) There is no time like the present ( )

11. **TELEPHONE** is to **VOICE** as **LETTER** is to

(1)stamp (2) post-office (3) writing (4) correspondence (5) envelope ( )

12. Which two statements prove **"JOHN IS A GOOD SWIMMER"?**

(1) Bob goes to the baths every day

(2) John and Bob are friends

(3) Bob won last year's swimming championship

(4) John beat Bob in a race last week

(5) John has challenged Bob to a race ( )

13. **MANNERS** are to **POLITE** as **MORALS** are to:

(1) politics (2) politeness (3) wealthy (4) virtuous (5) strong ( )

14. Which two statements prove that **"MR. SMITH OWNS SOME TAMWORTHS"?**

(1) Tamworths are better pigs than Berkshires

(2) One-eight of the pigs in that pen are Tanworths

(3) Most of the pigs in that pen are Berkshires

(4) At the pigs in that pen belong Mr. Smith

(5) Most of the farmers in the district own Tamworths ( )

15. Four of the following are alike in some way. Write the numbers of the other two in the brackets

(1) spire (2) church (3) flagpole (4) steeple (5) tower (6) hall

(and)

16. **OCEAN** is to **LAKE** as **CONTINENT** is to:

(1) river (2) land (3) mountain (4) Island (5) Europe ( )

GO STRAIGHT ON WITH THE NEXT PAGE

17. Which two of the following statements mean most nearly the same?

(1) Fire that's closest kept burns fiercest

(2) Set a thief to catch a thief

(3) A dog with a bone knows no friend

(4) Fight fine with fire

(5) Sow the wind, reap the whirlwind ( )

18. Three days in the week have the same number of letters. In the brackets write the first letter of the day which begins with the letter, which of the three comes first in the alphabet. ( )

19. **"ONLY PREFECTS WEAR A BADGE" ALL PREFECTS ARE IN FORMS VI"** Therefore, which one of the following statements is true? Write its number in the brackets

(1) All Form VI boys may wear a badge

(2) A boy wearing a badge is in Form VI

(3) All 1st XI boys may wear badges

(4) V Form Prefects do not wear badges

20. Four of the following are alike in some way. Write the numbers of the other two in the brackets.

(1) blame (2) accuse (3) indict (4) loath (5) censure (6) ape (and)

21. Which of the following statements mean most nearly the same?

(1) He who follows two hares will catch neither

(2) To blow and swallow at the same time is not easy

(3) He holds nothing fast who grasps at too much

(4) Despise the man who can blow hot and cold with the same breath

(5) It is easy to despise what you cannot obtain ( )

22. **FEW** is to **MANY** as **OCCASIONALLY** is to:

(1) seldom (2) never (3) every (4) often (5) always ( )

23. Four of the following are alike in some way. Write the numbers of the other two in the brackets.

(1) corrugated (2) involved (3) complicated (4) intricate (5) coarse (6) complete (and)

24. Which two of the following statements together prove that

"MR. REED DOES NOT LIVE IN HUME STREET"

(1) All the buildings in Hume Street are modern

(2) All the buildings in Hume Street are flats

(3) Mr. Reed lives in comfort

(4) Mr. Reed does not live in a flat

(5) Mr. Reed lives five miles from town

25. If these words were rearranged correctly to form a sentence, with what letter would be middle word begins? Is From a Molehill a Mountain a Thing Different ( )

26. **GATE** is to **FENCE** as **PORT** is to:

(1) land (2) coast (3) town (4) sea (5) destination ( )

27. Which two of the following statements mean most nearly the same?

(1) It's petty expenses that empty the purse

(2) Small gains bring riches in

(3) Even the weak are strong when united

(4) Constant dripping wears away the stone

(5) A chain is as strong as its weakest link ( )

28. Four of the following are alike in some way. Write the numbers of the other two in the brackets.

(1) ruler (2) heat (3) clock (4) thermometer (5) raingauge (6) yard) (and)

29. Which two of the statements mean most nearly the same?

(1) Repentance is poor consolation

(2) More haste less speed

(3) Quick decisions often breed regret

(4) He'll have a bucket of tears for a cup of joy

(5) Marry in haste, repent in leisure ( )

30. **DRAMATIST** is to **PLAY** as **COMPOSER** is to:

(1) orchestra (2) plano (3) symphony (4) performance (5) concert ()

31. Which two of the following statements together prove that **"TODAY IS COLDER THAN YESTERDAY"?**

(1) Every Friday this month was a cold day

(2) To-morrow is the first day of the month

(3) Last Thursday was a hot day

(4) The last day of each month this year has been the coldest day in the month

(5) Summer is nearly over ( )

32. Four of the following are alike in some way. Write the numbers of the other two in the brackets.

(1) fugitive (2) enemy (3) evacuee (4) escapee (5) prisoner (6) truant ( )

33. Which two of the following statements mean most nearly the same?

(1) A great fortune is a great slavery

(2) Better beans and bacon in freedom than cakes and ale in bondage

(3) Put a chain round the neck of a slave and the end fastens round your own

(4) Lean liberty is better than fat slavery

(5) Stone walls do not a prison make ( )

34. In a certain code the English word **BOARD** is writer **CODVI.** What would be English word BAD be in the code? ( )

35. Which two of the following statements mean most nearly the same?

(1) Forewarned is forearmed

(2) The loss which is unknown is no loss at all

(3) No man is happy that does not think so

(4) Uneasy lies the head that wears a crown

(5) Where ignorance is bliss, it is folly to be wise

36. BATTLE is to DUEL as CHORUS is to:

(1) twins (2) duet (3) selection (4) music (5) song ( )

LOOK BACK OVER YOUR WORK

APPENDIX VI

GUIDELINES FOR EVALUATING TEACHERS' PERFORMANCE DURING TRAINING ON THE USE OF PROBLEM SOLVING INSTRUCTIONAL STRATEGIES

Traits		Very good 5	Good 4	Average 3	Poor 2	V. poor 1
1	Teacher's ability to explain what problem solving is.					
2	Teacher's ability to state the steps of the Bio Problem Solving Model					
3	Teacher's ability to state behavioural objectives					
4	Teacher's judicious use of questions to elicit responses on the previous knowledge of the students in the subject matter					
5.	Suitable questions asked by the teacher to help students recognize the problem					
6	Students' ability to identify the problem					
7.	Students' ability to suggest ways of solving the problems.					
8.	Adequate usage of instructional materials to reinforce teaching and learning.					
9.	Ability of the teacher to guide students carry out investigation individually.					
10	Ability of the student to manipulate the materials while demonstrating the science process skills					
11	Ability of the teacher to co-ordinate class activities with effective class control					
12	Teacher's ability to use relevant questions to elicit responses from student in order to identify areas of difficulty in the topic taught					
13	Ability of teacher to give relevant assignment to prepare students for the next lesson					

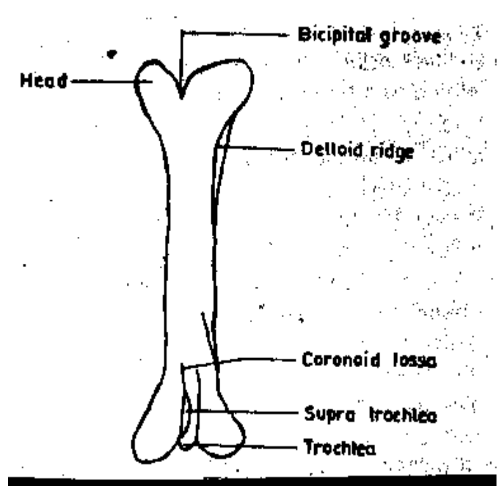
APPENDIX VII

GUIDELINES FOR EVALUATING TEACHERS' PERFORMANCE DURING TRAINING ON THE USE OF MODIFIED LECTURE METHOD.

	Traits	**V. good 5**	**Good 4**	**Average 3**	**Poor 2**	**V. poor 1**
1	Teacher's ability to state behavioural objectives					
2.	Teacher's judicious use of questions to elicit responses on the previous knowledge of the students in the subject matter					
3,	Teacher's knowledge of the subject matter					
4	Ability of the teacher to give out facts to the students					
5	Ability of the teacher to demonstrate the experiments					
6	Ability of the teacher to exercise class control.					
7	Teachers' ability to use relevant questions to elicit responses from students in order to identify areas of difficulty in the topic taught.					

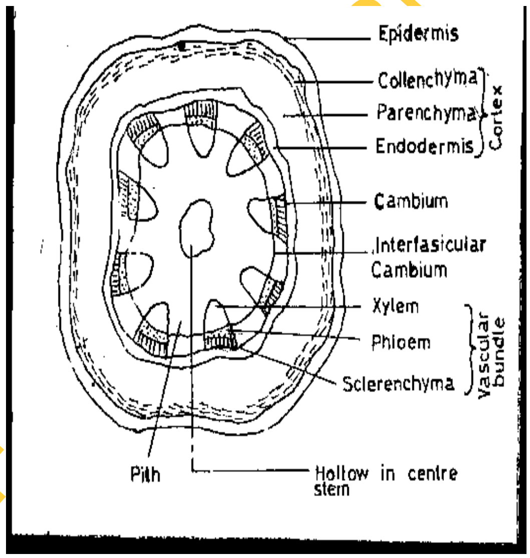
APPENDIX VIII

SCORING GUIDE FOR SCIENCE PROCESS SKILLS TEST IN TISSUES AND SUPPORTING SYSTEMS IN ANIMALS AND PLANTS.

No	Questions	Answer	Mark
1a	Arrange the bones of the fore-arm to make a lever system		
1b	What class of lever is represented in 1a?	Third class	1
1c(ii)	What is the name of the joint between Specimen B and F?	Hinge joint	1
1d .	Observe specimen A and B carefully. What are the names of the bones? (2 marks)	Specimen A = Femur Specimen B = Humerus	1 1
1e	Make a large labelled diagram 8 to 12cm long of the dorsal view of specimen B (10 marks)	Diagram of Dorsal view of specimen B (Humerus)  	

		Quality: MG (Magnification) x 1 to x 3 SZ (Size) 8cm to 12cm CL (Clarity of lines, not wooly not broken) NL (Neat labels, horizontal lines, not crossed, ruled guide line, horizontal labels **Details:** DR (Deltoid ridge shown) CF (Coronoid fossa shown) PH (Prominent head shown) FS (Foramen/Supra trochlear foramen shown) **Labels:** Groove, Shaft, Deltoid ridge, Coronoid fossa, Supra trochlear foramen, Trochlea, head, tuberosity, condyle Any 4 x ½ *Only correct spellings will score.	 1 1 1 1 1 1 1 1 2
1f	Given the following specimens A,B,C,D, demonstrate how the bones articulate with specimen A at the anterior and posterior ends.		
1g	Name the type of joints associated with specimen A and B at the proximal end.	Ball and Socket joint	2

1h	State ONE function of specimen A and ONE of specimen B. (2 marks)	A = Articulate with the acetabulum of the pelvic girdle to provide movement in all directions B= Articulate with the glenoid cavity of the scapula to provide movement in all directions	1/2 1/2
1i	Name Two Structures found in green multicellular plants that are comparable to specimen A and specimen B. (2 marks)	Xylem, sclerenchyma, collenchyma, wood, parenchyma. Any 2 x 1	2
1j.	State any Two muscles attached to specimen B (2 marks)	Biceps, Triceps (without s, it is wrong) ***Total 21 marks***	2
2	How would you explain to J.S. three students that some tissues in the plant stem carry out the function of conducting water from one part of the plant to the other. The experimental set-up illustrates this process		

	Now answer these questions.		
2a	What is the aim of this investigation? [1mark]	To show the path of movement of water through a plant.	1
2b	With a razor blade or scalpel, cut a portion of the stem and label it specimen E. Make a large labelled drawing 8-10cm long of the cut surface of specimen C. (10 marks)		
		Quality:	
		MG(Magnification) x 12 - x 14 no decimal	1
		SZ (Size) 8cm to 12cm	1
		CL (Clearity of lines, not wooly, not broken)	1
		NL (Neat Labels, horizontal lines, not crossed, rule guide line, horizontal labels.	1
		Details:	
		SP (Stained Portion shown)	1
		VR (Vessels arranged in a ring	1

		WP (Wide Pith) EP (Epidermis thin) **Labels:** Epidermis, cortex, cambium, pith, xylem, Phloem, hollow in centre of stem, Endodermis sclerenchyma. Any 4 x ½	1 1 2
2c	Name the tissue that is stained. (1 mark)	Xylem	1
2d	State Two Functions of the stained portion. (2marks)	(ii) For conducting water and mineral salts (iii) Strength and support to the plant	2
2e	State Two possible effects of the absence of stained portion in the stem of a plant. (2 marks)	(i) death of the plant (ii) loss of resilience in the plant	2
2f	How are the vascular bundles arranged? (1 mark)	In ring /circle /circular	1
2g	What is the effect of this form of arrangement? (1 mark)	The tree trunks are able to grow in width or girth	1
2h	How would you describe the arrangement of the vascular bundles in monocotyledonous stem?	Vascular bundles are scattered.	1
		Total Mark =40	

APPENDIX IX

Bio PROBLEM SOLVING MODEL

PRE-TREATMENT STAGE

Duration: 1 Week

Topic: Use of Bio Problem Solving Model (BioPSOM)

Performance Objectives (1) Define the terms problem and problem solving

(2) Identify the major steps involved in BioPSOM

(3) Solve problems based on any course unit taught.

Ability: Mixed ability (high, medium and low)

PRESENTATION

INTRODUCTION

Teacher puts this question to the students. Can a maize grain be regarded as a fruit?

From the above question, there is a problem.

The teacher explains what problem and problem solving is.

Problem refers to a situation in which an individual is required to carry out a task he has not previously encountered and for which externally provided instructions do not dictate how the task should be done.

Problem Solving: These are activities the learner is expected to carry out in stages to arrive at a solution.

Students get involved with laboratory activities to be able to give answers to the problem raised by the teacher.

Step I: Teacher leads a discussion on the steps of the BioPSOM while students listen and make notes.

- Recognition of problem
- Gathering and processing information
- Experimentation
- Analysis of Results (Report, Draw and Discuss Results)
- Evaluation

Step II: Based on the (BioPSOM), students are requested to solve a practical problem. Teacher sets in a problem on concepts which students did in SS I. For example, how will you determine that a soil sample consist of different soil particles?

Step III: Teacher leads the students on the steps as in BioPSOM to solve the problem:

i. **Recognition of problem**

a. What exactly am I required to do?

b. What materials do I need for this investigation?

c. How do I solve this problem?

ii. **Gathering and processing information**

Students refer to their theoretical background in forms of facts, principles and theories relevant to the problem. The teacher can help students draw on their knowledge by asking relevant questions or making statements to guide their thinking and investigation.

iii. **Experimentation**

a. Students provide the materials for experimentation – soil sample from different locations, a stick to be used as stirrer, glass container and water

b. Students carry out the laboratory activities

c. Students take note of all experimental happenings

iv. **Analysis of Results (Report, Draw and Discuss Results)**

Students make reports, draw the experimental set-up and discuss results.

v. **Evaluation**

Teacher evaluates the appropriateness of the solution arrived at. Teacher assesses students' knowledge outcomes based on the performance activity and encourages the students to make an objective criticism of the problem solving model employed for the teaching and learning process.

ASSIGNMENT: In the food substances provided, how do you find out the food nutrients?

APPENDIX X

GAYFORD PROBLEM-SOLVING HEURISTICS (GPSH)

PRE-TREATMENT STAGE

Duration: 1 Week

Topic: Use of Gayford Problem-Solving Heuristics (GPSH)

Performance Objectives: (1) Define the terms problem and problem solving

(2) Identify the major steps involved in GPSH

(3) Solve problems based on any course unit taught.

Ability of students: Mixed ability (high, medium and low)

PRESENTATION

Introduction

Teacher puts this question to the students. Can a maize grain be regarded as a fruit?

From the above question, there is a problem.

The teacher explains what problem and problem solving is.

Problem refers to a situation in which an individual is required to carry out a task he has not previously encountered and for which externally provided instructions do not dictate how the task should be done.

Problem Solving: Problem solving is the process by which a possible solution is sought for to a defined problem

Students get involved with laboratory activities to be able to give answers to the problem raised by the teacher.

Step I: Teacher leads a discussion on the steps of the Gayford Problem-Solving Heuristics while students listen and make notes.

1. Grouping of students.
    - Teacher puts the students into groups of ten each.
2. Question and problem generation
    - Students write down the questions they want to ask.
    - They discuss this question in their groups.
    - Students write down exactly what they think the problem is.

- Students think about how someone else is likely to judge how successful they have been in solving the problem. They write this down.

3. Students refer to what they have learned which may help them in problem solving.
4. Experimentation
   - Students select appropriate strategy for the solution of the problem.
   - Students carry out activities using the materials provided by their teacher
   - Students discuss among themselves to find out if the experimental procedure is appropriate or if they need to make minor or major changes.
   - Students try to identify any further problem they need to investigate before arriving at the solution.
5. Evaluation –Groups measure their success.

Step II: Based on the GPSH, students are requested to solve a practical problem. Teacher sets in a problem on concepts which students did in SS I. For example, how will you determine that a soil sample consist of different soil particles?

Step III: Teacher leads the students on the steps as in GPSH to solve the problem:

- Students ask among themselves what the problem is. They generate questions, for example, what is soil? What kind of soil has the teacher provided for us?
- Students make several attempts in breaking down the problem to ensure that they understand the problem statement.
- Students refer to what they had learned in school or anywhere else that will help them in solving the problem.
- Students discuss in their groups the different ways of tackling the problem, for example, the soil can be put in a sieve and shaken to separate the particles or it can be put in a jar of water and stirred and allowed to settle down.
- Students select the best method using the sedimentation method.
- Students engage in laboratory activities as a group.
- Students discuss among themselves to find out if the experimental procedure is adequate or they need to make minor or major changes. For example, do they need more soil and water, or is the soil texture appropriate?
- Students try to find out if there are new problems to be addressed to help them arrive at the solution.
- Students evaluate their success.

APPENDIX XI

GUIDE TO THE PREPARATION OF INSTRUCTIONAL MATERIALS

Topic: Preparation of Instructional Materials, the bones of the Mammalian Skeleton

Class: Experimental group 1 (Bio Problem Solving Model Group)

Performance Objectives: At the end of the lesson, students should be able to

1. Cook the mammal until the flesh becomes very soft
2. Separate the flesh from the bone
3. Wash the bones with hydrogen peroxide
4. Produce a complete/whole mammalian skeleton
5. Arrange the bone on a hard wooden board
6. Prepare a solution of red dye

Ability of Students: Mixed ability (high, medium and low)

Teaching and Learning Materials: A small mammal (rabbit), knife, cooking pots, source of fire, hydrogen peroxide, wooden board, cello-tape etc.

PRESENTATION

INTRODUCTION

Step I: Review the previous lesson on the steps of the problem solving model by asking the students oral questions. For example, define problem? What is problem solving? Name the steps in BioPSOM.

Step II: Teacher leads students in discussion on the preparation of the mammalian skeleton.

Step III: Teacher guides the students on the preparation of the bones of the mammalian skeleton.

The teacher asks the students the following questions:

1. What is a Mammal?
2. How is a mammal different from other animals?
3. Give examples of mammals.
4. What is the likely size of the mammal to be used for the preparation of the skeleton? Why?
5. In what state can the mammal be used?
6. How do we get it into that state?

Teacher responds to students answers. Students then proceeds to the preparation stage of the mammalian skeleton under the teacher's guidance.

- Kill the Mammal
- Cook the mammal carefully for between 1-2 hours. Why cook the mammal for such a long time?
- Separate the flesh from the bone. How can this be done?
- Then wash the bones, with a solution of hydrogen peroxide. Why use hydrogen peroxide and not water or soap water?
- Arrange produced bones on a hard wooden board or cardboard held in place with cello-tape.
- Clean up is done by the students after the skeleton preparation.

Step IV: Students are given opportunities to ask questions.

Teacher asks student's questions to asses each step of the preparation process. Also students prepare solution of red dye by putting a tablespoonful of red dye into a 30 ml of water in a glass container. This is thoroughly stirred with a glass rod to obtain a uniform colour.

Assignment: Why are animals able to stand upright, move the body and perform various activities?

APPENDIX XII

LESSON PLAN ON PROBLEM SOLVING INSTRUCTIONAL STRATEGIES AND MODIFIED LECTURE METHOD

Lesson 1:

Duration: 1 Hour

Class: SS2

Topic: Mammalian Skeleton

Sub-Topic: Bones of the axial skeleton

Performance Objectives: The students should be able to:

1. Identify the bones of the vertebral column.
2. State the distinguishing features of each bone.
3. Compare the different bones.
4. Draw and label correctly the bones of the axial skeleton.

Ability of Students: Mixed Ability (high, medium and low)

Teaching and Learning Materials: Bones of the mammalian skeleton and charts.

Previous Knowledge: Students on Bio problem solving instructional strategy group prepared the instructional materials needed for the learning activities.

PRESENTATION (For Problem Solving Groups)

Introduction: Teacher revises the previous lesson on the applicability of the problem solving instructional strategies.

Step I: Teacher leads students in these exercises to begin the lesson. A rolled piece of well mixed clay of length 5cm will not stand upright no matter how much you try to make it stand. What probable reasons can you suggest to explain why it will not stand on its own? Teacher further asks students to suggest what they can do to make the rolled piece of clay to stand upright.

Step II: Teacher defines skeleton and states the types of skeleton.

Step III: Teacher leads and gives explanation on the bones of the axial skeleton using the mounted mammalian skeleton and the skeletal bones for students in problem solving groups.

Strategy Implementation:

Teacher presents students in the problem solving groups with problems. Problems are not presented to the students in the modified lecture method group.

Problem: You are provided with the bones of the forearm. Demonstrate the first class lever. Identify the bones of the forearm. Make a labeled drawing 8 – 10cm long of specimen A to show its essential features. Demonstrate how specimen C and D articulate with specimen A at the anterior end and posterior end.

Solution: Students refer to their theoretical knowledge in form of facts, principles and theories relevant to the problem.

BIOPSIS	GPSH	MLM.
Each student solves the problem on his/her own following the steps, on Bio Problem Solving Model	Students are placed in groups of ten. They solve the problems following the steps in Gayford Problem-Solving Heuristics.	Teacher presents the lesson in form of lecture. Teacher defines the skeleton and gives explanation on the bones of the axial skeleton. Students draw them and write their notes.
Evaluation: Teacher asks questions to assess each stage of the solution process and to assess attainment of objectives.		Teacher asks students questions to assess attainment of objectives

Assignment: Find out the bones that make up the appendicular skeleton.

LESSON PLAN ON PROBLEM SOLVING INSTRUCTIONAL STRATEGIES AND MODIFIED LECTURE METHOD

Lesson 2:

Duration: 1 Hour

Class: SS2

Topic: Mammalian Skeleton

Sub-Topic: Bones of the appendicular skeleton

Performance Objectives: The students should be able to:

1. Identify the bones of the appendicular skeleton.
2. State the distinguishing features of each bone.
3. Compare the different bones.
4. Draw and label correctly the bones of the appendicular skeleton.

Ability of Students: Mixed Ability (high, medium and low)

Teaching and Learning Materials: Bones of the mammalian skeleton and charts.

PRESENTATION (For Problem Solving Groups)

Introduction: Teacher revises the previous lesson on the bones of the axial skeleton by asking students some oral questions, for example, what bones make up the vertebral column? Where is it located in the body? Correct student mistakes.

Step I: Teacher explains the lesson for the day using the mounted mammalian skeleton. Teacher asks student questions on the position, size, shape, location, arrangement of different bones. Teacher leads the students to identify the bones of the appendicular skeleton. Teacher explains the main distinctive features while the students state the differences between the bones.

Strategy Implementation:

Teacher presents students in the problem solving groups with problems. Problem is not presented to students in the control group.

Problem: How would you identify specimen D and E showing their essential features? State and show how specimen D is adapted to articulate with specimen F at the proximal end.

Solution: Students refer to their theoretical knowledge in forms of facts, principles, and theories relevant to the problem.

BioPSIS Group	GPSH Group	Control Group
Each student solves the problems on his/her own following the steps in the Bio Problem Solving Model	Students are placed in groups of ten. They solve the problems following the steps in Gayford Problem-Solving Heuristics	The teacher presents the lesson in form of lecture. Teacher explains the topic and carries out the activities
Evaluation: Teacher asks questions to assess each stage of the solution process and to assess attainment of objectives.		Teacher asks students questions to go over the lesson.

Assignment: Assignment are given to students on the lesson and to prepare them for the next lesson. What makes movement of the body possible? What is the principal action of the muscles in your forearm?

LESSON PLAN ON PROBLEM SOLVING INSTRUCTIONAL STRATEGIES AND MODIFIED LECTURE METHOD

Lesson 3:

Duration: 1 Hour

Class: SS2

Topic: Mechanism of support and movement in animals.

Sub-Topic: (i) Types of joint

(ii) Movement at joints in vertebrates

Performance Objectives: The students should be able to:

1. Identify joints in the mammalian body.
2. State the types of movable joints with specific examples
3. Describe how movements is brought about in mammals

Ability of Students: Mixed Ability (high, medium and low)

Teaching and Learning Materials: Bones of the mammalian skeleton, students, chalkboard.

Previous Knowledge: Students have done work on the axial and appendicular skeleton.

PRESENTATION (for problem solving groups)

Introduction: Teacher revises the previous lesson on the axial and appendicular skeleton and asks the students some oral questions. For example, what is a skeleton? Name the bones of the axial and appendicular skeleton and so on.

Step I: Teacher begins the lesson by asking the students to suggest what happens if they

(i) Take their biro from the table and use it to scratch their back.

(ii) Bend their necks forward, backward and sideways.

(iii) Bend their arms at the elbow

(iv) Turn their entire right and left hands round, swing their right legs round.

(v) Grip firmly with their right hand the muscle in the upper part of the left arm and try to bend the left arm.

(vi) Straighten the arm without releasing the grip.

Teacher corrects students' responses

Step II: Teacher leads a discussion on joints and how movement in animals is achieved.

Strategy Implementation:

Teacher presents students in the problem solving instructional strategy group with problems. Problem is not presented to the students in the control group.

Problem If your backbone is made up of a long piece of bone, do you think you will be able to bend your back. Why are you able to bend your arm and turn your leg round? Demonstrate these using the specimens provided and draw them.

Solution Students refer to their theoretical background in forms of facts, principles and theories relevant to the problem.

BioPSIS Group	GPSH Group	Control Group
Each student solves the problems on his/her own following the steps in the Bio Problem Solving Model	Students are placed in groups, 10 each they solve the problems following the steps in Gayford Problem-Solving Heuristics	The teacher explains what joint is, types of joints and how movement in animals is achieved. Teacher demonstrates the different joints.
Evaluation: Teacher asks questions to assess each stage of the solution process and to assess attainment of objectives.		Teacher asks students questions to go over the lesson.

Assignment: Find out if plants have supporting tissues. What are they? What do they do for the plants?

LESSON PLAN ON PROBLEM SOLVING INSTRUCTIONAL STRATEGIES AND MODIFIED LECTURE METHOD

Lesson 4:

Duration: 1 Hour

Class: SS2

Topic: Supporting Tissues in Plants

Sub-Topic: (i) Types of supporting tissues in plants.

(ii) Mechanism of support in plants.

Performance Objectives: The students should be able to:

1. Identify supporting tissues in plants.
2. Carry out activities to identify these tissues
3. Draw the supporting tissues in plants

Ability of Students: Mixed Ability (high, medium and low)

Teaching and Learning Materials: Water leaf plant, water, beaker, test tube, blade/scalpel, hand lens, paper, pencil, glass tube and so on.

Previous Knowledge: Students have done work on joints and mechanism of support in animals.

PRESENTATION (Only For Problem Solving Groups)

Introduction: Teacher discusses this statement with the students.

i. On a windy day, trees can be seen bending and twisting in response to the action of the wind. Surprisingly, these trees still come back to their normal position. What can possibly account for the trees ability to maintain and regain their resilience?

Step I: Teacher explains the types of supporting tissues and the role they play in giving support to the plant and the mechanism of support in plants.

Step II: Students engage in laboratory activities.

Strategy Implementation:

ii. Teacher presents students in the problem solving instructional strategy group with problems. Problem is not presented to the students in the control group.

Problem Do plants take in nutrients? How would you explain to JS Two students that some tissues in plants carry out the function of transporting water from one part of the plant to another? Illustrate your observation by making a labeled drawing of 7cm to 8cm in diameter of the plant tissue distribution as seen using a hand lens.

Solution: Students refer to their theoretical knowledge in form of facts, principles and theories relevant to the solution of the problem.

BioPSIS Group	GPSH Group	Control Group
Each student solves the problems on his/her own following the steps in the Bio problem solving model.	Students are placed in groups of ten. Each group solves the problems following the steps in Gayford Problem-Solving Heuristics.	The teacher explains the types of supporting tissue and draws them on the chalk board for the students to draw.
Evaluation: Teacher asks questions to assess each stage of the solution process. Teacher assess students knowledge out comes based on their performance activity.		Teacher asks students questions to assess attainment of objectives.

Assignment: What tissues in plants can bring about flexibility in plants?

LESSON PLAN ON PROBLEM SOLVING INSTRUCTIONAL STRATEGIES AND MODIFIED LECTURE METHOD

Lesson 5:

Duration: 1 Hour

Class: SS2

Topic: Function of Supporting Tissues in Plants and Animals.

Performance Objectives: The students should be able to:

1. State the functions of mammalian skeleton
2. State the functions of supporting tissues in plants

Ability of Students: Mixed Ability (high, medium and low)

Teaching and Learning Materials: Bones of the mammalian skeleton, a thin slice of stem.

Previous Knowledge: Students have done work on the bones of the mammalian skeleton, joints, internal structure of stem.

PRESENTATION (Only For Problem Solving Groups)

Introduction: Teacher revises the previous lessons on the bones of the mammalian skeletons and plant tissues by asking students same oral questions, for example, what are the plant tissues? What bones make up the appendicular skeleton? Correct students' mistakes.

Step I: Teacher leads a discussion on the functions of mammalian skeleton and supporting tissues in plants.

Step II: Student carry out activities on the functions of mammalian skeleton and supporting tissues in plants.

Strategy Implementation:

Teacher presents students in the problem solving instructional strategy group with problems. Problem is not presented to the students in the control group.

Problem The skeleton is a rigid framework, how does the body overcome this? Does the mammalian skeleton in animals and supporting tissues in plants perform any role? How would you demonstrate some of these roles?

Solution: Students refer to their theoretical knowledge in forms of facts, principles and theories (and strategies) relevant to the solution of the problem. The teacher can help students draw on their knowledge by asking relevant questions or making statements to guide their thinking and investigation.

BioPSIS Group	GPSH Group	Control Group
Each student solves the problems on his/her own following the steps in the Bio problem solving model	Students are placed in groups, of ten. Each group solve the problems following the steps in Gayford Problem-Solving Heuristics	The teacher explains the different functions of the mammalian skeleton. Teacher describes the role supporting tissues and play to give the plant support, rigidity.
Evaluation: Teacher asks questions to each stage of the solution process and to assess attainment of objectives.		Teacher asks students questions to assess student's knowledge outcomes.

Assignment: What are the structures that make biting and chewing possible in mammals?

LESSON PLAN ON PROBLEM SOLVING INSTRUCTIONAL STRATEGIES AND MODIFIED LECTURE METHOD

Lesson 6:

Duration: 1 Hour

Class: SS2

Topic: Dentition in Mammals

Sub-Topic: Types of teeth. The structure of a tooth

Performance Objectives: The students should be able to:

1. Identify the types of teeth
2. Identify the parts of tooth
3. Draw and label correctly the structure of tooth.

Ability of Students: Mixed Ability (high, medium and low)

Teaching and Learning Materials: Head of rabbit, teeth of mammal, for example, goat, rabbit, upper and lower jaws of goat or rabbit. .

Previous Knowledge: Students have completed work on mammalian skeleton.

PRESENTATION (for problem solving groups)

Introduction: Teacher goes over the assignment given to the students. Few questions are asked

Step I: Teacher explains what dentition in mammals is.

Step II: Using the head of rabbit students examine the arrangement, shape and location of the teeth. Students identify and observe the parts of a tooth and make notes.

Strategy Implementation:

Teacher presents students in the problem solving instructional strategy group with problems.

Problem If you were to eat yam with vegetable stew and meat for breakfast, what parts of the body will enable you get this food into your stomach as smaller bits? How would you identify and illustrate their essential features.

Solution: Students refer to their theoretical knowledge in forms of facts, principles and theories (and strategies) relevant to the problem. The teacher can help students draw on their knowledge by asking relevant questions or making statements to guide their thinking and investigation.

BioPSIS Group	GPSH Group	Control Group
Each student solves the problems on his/her own following the steps in the Bio problem solving model.	Students are placed in groups of ten. Each group solve the problems following the steps in Gayford Problem-Solving Heuristics.	Teacher introduces the lesson by leading discussion on dentition in human being. Teacher describes the types of teeth, explains the structure of a tooth and how to care for the teeth.
Evaluation: Teacher asks questions to assess students' knowledge outcomes.		Teacher asks questions to assess student's knowledge outcomes.

Assignment: Observe a cow or goat feeding on vegetation and note the method of chewing.

LESSON PLAN ON PROBLEM SOLVING INSTRUCTIONAL STRATEGIES AND MODIFIED LECTURE METHOD

Lesson 7:

Duration: 1 Hour

Class: SS2

Topic: Feeding and Digestive Adaptations in herbivores, for example, rabbit

Performance Objectives: The students should be able to:

1. State the diet of a herbivore
2. Identify the teeth of a rabbit
3. State the modification of the teeth
4. Describe the digestive adaptation in rabbit.

Ability of Students: Mixed Ability (high, medium and low)

Teaching and Learning Materials: Skull of rabbit, teeth.

Previous Knowledge: Students have done work on dentition in mammals.

PRESENTATION (Only for Problem Solving Groups)

Introduction: Teacher revises previous lesson with the students by asking them some oral questions, for example, what are teeth? State the parts of a tooth. Correct student's mistakes.

Step I: The teacher leads a discussion on feeding and digestive adaptation in a rabbit. Students examine the skull of the rabbit, note the arrangement of teeth in the lower and upper jaws.

Strategy Implementation:

Teacher presents problems to the students in the problem solving instructional strategy groups.

Problem (a) Specimen J is a component structure obtained from a small mammalian skeleton. Examine specimen J carefully and answer the following questions. What part of the mammal was specimen J obtained from?

(ii) What is the name given to specimen J?

(bi) Make a labeled drawing of 8cm to 10cm long of the lateral view of specimen J.

(ii) Suggest the feeding habitat of the animal.

(c) Describe the observable structures in dentition of specimen J and their adaptations to the feeding habits of the animal.

Solution: Students refer to their theoretical knowledge in forms of facts, principles and theories (and strategies) relevant to the problem. The teacher can help students draw on their knowledge by asking relevant questions or making statements to guide their thinking and investigation.

BioPSIS Group	**GPSH Group**	**Control Group**
Teacher encourages students to solve the problem based on the stages in Bio Problem Solving Model.	Students are placed in groups of ten. Each group solves the problem following the steps in Gayford Problem-Solving Heuristics.	The teacher revises previous lesson with the students. Teacher explains the diet of a herbivore and teeth modification. Teacher shows the students the arrangement of teeth in the lower and upper jaws. Teacher describes feeding adaptations in rabbit.
Evaluation: Teacher asks questions to assess the attainment of objectives.		

APPENDIX B1a-b

(a)

(b)

Students in the Bio Problem-Solving Instructional Strategy group slaughtering the rabbits

APPENDIX B1 c-d

(c)

(d)

Students in the Bio Problem-Solving Instructional Strategy group preparing the bones of the mammalian skeleton.

APPENDIX B1e-f

(e)

(f)

Students in the Bio Problem-Solving Instructional Strategy group preparing the bones of the mammalian skeleton.

APPENDIX B1g-h

(g)

(h)

Teacher and students in the classroom during the teaching-learning process

APPENDIX B1i-j

(i)

(j)

Students at work solving the experimental problems

APPENDIX BI k-l

(k)

(l)

Students at work during the science process skills test

APPENDIX B1m

(m)

Students at work during the science process skills test

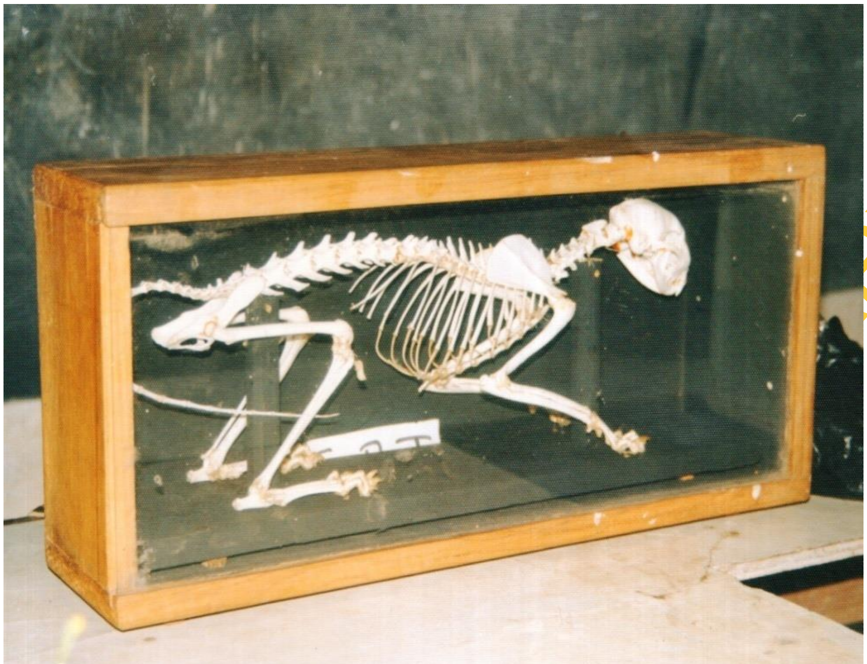
APPENDIX B 1 n-o

(n)

(o)

Teacher examining the student on-one-to-one basis demonstrating the science process skills

APPENDIX B 1p



(p)

The mammalian skeleton of the rabbit