CHAPTER ONE

INTRODUCTION

Background to the Study

The explosion of knowledge and the nature of learning, combined with the growing power of technology present learners with new and constantly changing situations. With the increasingly diverse knowledge explosion and fast developing technological innovations, there is need for secondary school students to acquire science process skills that will enable them function effectively in the larger society. Most graduates of the education system are aware of scientific processes but lack the ability to apply them in situations of everyday living (Karamustafaoglu, 2011). For this reason, science students are expected to acquire both science literacy and science process skills to be able to function effectively in the modern age of science and technology.

Scientific literacy is considered as an important part of science education because it enables each student to become a scientifically literate person and make informed decisions (Akinsayo, Ajayi & Salomi, 2014). Students who are science literate, can communicate their ideas orally or in writing. To be science literate individuals, need to have a substantial background in science literacy and content knowledge in order to provide solutions to scientific issues (Balgopal & Wallace, 2013). In addition, students can use scientific evidence to draw inferences to establish critical thinking skills. Students can evaluate scientific evidence, make claims, understand the development of scientific knowledge, and make real life connections through extension of scientific concepts. Metz (2012) noted that as an important part of science literacy, writing in science classrooms can effectively assist all students to understand questions, claims, scientific reasoning,

evidence, and claims-evidence relationship in science. Thus, science literacy serves as a foundation to effective learning for all the science related subjects in secondary schools and acquisition of science process skills.

Science process skills (SPS) are a set of broadly transferable abilities that reflect what scientists do (Mei, Kaling, Xingi & Khoon, 2007). They have been described as mental and physical abilities and competencies which serve as tools needed for the effective study of science and technology as well as problem solving, individual and societal development (Akinbobola & Ado, 2007). Science process skills are categorized into basic science process skills and integrated science process skills (Mei et al., 2007). The basic science process skills include observing, inferring, experimenting, communicating, classifying and predicting.

Over the years, biology teachers have been faced with the problem of helping students improve achievement and acquire science process skills, of which acquisition of science process skills is the major goal of teaching science (Ali, Toriman, & Gasim, 2014). According to Lenor (2015), no two students enter a classroom with identical abilities, experiences and needs. Learning style, language proficiency, background knowledge, readiness to learn and other factors can vary within a single class group. Regardless of the learners' individual differences, students are expected to master the same concepts, principles and skills. To cater for the different learning abilities of the students, teachers are expected to be well equipped in the pedagogical content knowledge as well as strategies of passing scientific knowledge and science process skills to the learners in order to improve student's achievement.

The poor academic achievement of secondary school students in biology as indicated in the annual report of the West Africa Examination Council (WAEC) reveals poor achievement in biology education (Bella, 2014). According to Osuafor and Okonkwo (2013), statistics from May/June 2007 – 2012 WAEC examinations revealed that the percentages of candidates who passed WASCE at credit level and above (grade 1-6) in biology were as follows; 15.79 in 2007, 31.29 in 2008, 31.39 in 2009, 38.75 in 2010, 36.56 in 2011 and 31.81 in 2012.

The WAEC chief examiner's report shows that from 2010 to 2018 certain weaknesses were exhibited by biology students. Among the common weakness were wrong spelling of technical terms, not attempting compulsory questions, lack of sequence in life cycles of insects and animals, (e.g. life cycle of toads and metamorphosis in butterfly), inability to define test cross correctly, poor understanding of sexual reproduction in organism like flowering plants, poor attempt in answering questions requiring detailed explanations, poor response to the questions on adaptation in xerophytes. Other weaknesses include: drawing flowering plant instead of the transverse section of a stem, inability to give detailed description of terms relating to germination of seeds, inability to compare succession and competition, draw according to specification, classify organisms, understand what observable difference means, relate differences in a tabular form, march structures with function correctly and poor grammatical expressions.

The poor achievement in biology and these identified weaknesses may be attributed to lack of effective teaching method or to the use of conventional teaching methods, non-availability of modern laboratory and learners' background knowledge. Conventional teaching methods are teacher-centered and include the use of lectures and discussions,

while the problem solving element is presented by and/or discussed with the teacher, the syllabus, the teaching materials and the student assessments are determined by the teacher and transmitted to students in various lectures. In teaching biology practical, teachers often adopt demonstration method which involves teacher modelling the experiment for the students. The students are thereafter divided into groups with group leaders who carry out the experiment on behalf of their group. Although the students did not individually carry out the experiments on their own, they are evaluated individually. This approach reduces the involvement of the students but could affect students' achievement and acquisition of science process skills effectively. There is need for more innovative methods of teaching that could positively enhance students' achievement. One of such teaching method is the science writing heuristics.

SWH is a teaching approach that provides learners with an experimental (heuristic) template, or plan, to guide their science laboratory activities using experiments, arguments, negotiation and writing. This heuristic template, or plan, is designed around some questions. The questions prompt the learner to utilize scientific thinking and reasoning through critically analyzing their prior knowledge. This is followed by students negotiating their own meaning of scientific concepts, developing links between claims and evidence, and constructing explanations and generalizations based on relationships observed (Arnold, 2011). In this approach, the students are placed in the position of independent discoverers and students must make a claim (inference) about what was learned through the laboratory activity and provide evidence to support that claim. The successful implementation of the SWH teaching approach requires a student-centered learning environment (Greenbowe, Poock, Burke & Hand, 2007).

Science writing heuristics (SWH) is one of the new teaching methods in science. The word heuristics means to discover: SWH is the teaching of science through scientific writing to discover scientific knowledge and process skills. SWH teaching approach is mainly used in the teaching of practical orientated topics in science. According to Drobitsky (2015), the SWH process begins with a discourse between the students and the teacher at the students' current level of understanding. This provides an avenue for scaffolding of knowledge by students and enabling the teacher to better address the students' specific learning style and pre-knowledge. With carefully planned and guided prompting, students' questioning will occur naturally, leading students to want to find out or discover knowledge for themselves. If necessary, the teacher uses prompts to redirect students when they begin to go astray from the desired topic under discussion. In this study, science writing heuristics was used as a teaching method and a tool to assess students' achievement and acquisition of science process skills in biology.

SWH provides learners with a experimental template to guide their science activities and reasoning in writing, as well as provides teachers with a template of suggested strategies that could enhance students' learning from laboratory activities (Drobitsky, 2015). It is a bridge between informal, expressive writing modes that foster personally constructed science understandings and more formal public writing modes that focus on organized forms of reasoning in science. The template for student thinking, prompts learners to generate questions, claims and evidence, for making an argument based on valid reasoning.

SWH helps students develop a deeper understanding of the big ideas of science contents through the phases of the students' template/plan. The template requires the

student to solve a number of problems experimentally; the experiment starts with questions in order to find answer and a writing task, which often follows a continuous cycle of negotiating and clarifying meanings and explanations with their peers and teachers. Comparing their ideas with those of others, and considering how their ideas have changed through this process. Thus, the emphasis of the SWH focuses on the collaborative nature of scientific activities or scientific arguments. According to McDermott (2010), SWH incorporates writing as a learning tool rather than just a reporting tool. When utilizing this type of writing (writing-to-learn), students generate and clarify their understanding of scientific concepts for themselves, rather than simply communicating with a teacher for evaluation and also develop science process skills in the course of the experiments.

Several studies like those of Şen and Sezen-Vekli (2016) and Arnold (2011), have shown that scientific process skills can be developed by using inquiry and science writing heuristics (discovery learning). It can also be developed through investigative approach of teaching and learning science that gives them opportunities to practice these skills. Exposing biology students to scientific skills through SWH teaching approach in practical lessons could help equip them with the capacity of thinking critically, generate ideas about how the world around them works, and how living things function in their environment. They can then apply the knowledge and skills learnt in the classroom to their everyday lives unlike when they learn through conventional methods which make it hard to acquire skills.

Conventional teaching method is a teacher-centred method whereby the teacher is seen as an authority imparting knowledge to the students. It could involve a mix of different methods, but it is mainly the lecture or expository methods that are commonly

used. Although, conventional method of teaching has been shown in a number of studies to be less effective compared to other innovative methods, teachers still adopt them for teaching and learning. This is because conventional method is suitable for teaching large groups of students and for covering large content area. Conventional method has however, not proven effective for male as well as female students.

Gender is one of such factors also mentioned in various research studies to have considerable influence on students' academic achievement especially in science subjects (Ezeano, 2013). It is the range of physical, biological, mental and behavioural characteristics pertaining to and differentiating between the female and male population (Gunel, 2006).

The importance of examining performance in relation to gender is based primarily on the socio-cultural differences between girls and boys. Some vocations and professions are today seen as female jobs while others are also seen as male jobs. In the society tasks that are regarded as complex and difficult are allocated to males whereas females are expected to handle the relatively easy and less demanding tasks. As a result of this way of thinking, the larger society has tended to see females as a weaker sex. Consequently, an average Nigerian girl goes to school with these fixed stereotypes (Femi & Adewale, 2012).

A number of studies have been expressed about gender stereotype in the acquisition of science process skills, while some looked at science education in general and biology in particular as a female dominant discipline. Others view biology as a field of study that is open to both males and females. According to Gunel (2006), and Nwafor, Obodo and Okafor (2015), males show more interest in learning science, acquire and utilize science process skills in everyday living more than females.

Statement of the Problem

The problem that necessitated this study is secondary school students' poor performance and lack of acquisition of science process skills in biology as indicated in the annual report of West Africa Examination Council (WAEC). Biology education is expected to equip students with the relevant knowledge and skills that will enable them know how their body function as humans, the complexity of nature and how to apply the knowledge and skill acquired in their everyday living. Unfortunately, most of the teaching methods/approaches used in the teaching of the subject in schools do not give room for students to explore, inquire, acquire scientific knowledge and process skills. This has necessitated the search for more effective methods of teaching biology in schools to enhance the achievement of students in biology at external examinations and acquire science process skills required to for future studies.

The Science Writing Heuristic (SWH) is one of the teaching methods that could improve students' learning process, especially in laboratory settings. The researcher was therefore, moved to determine the effects of science writing heuristics (SWH) on achievement and acquisition of science process skills by secondary school students in biology.

Purpose of the Study

The purpose of this study was to determine the effects of science writing heuristics teaching approach on secondary school students' achievement and acquisition of science process skills in biology. Specifically, the study determined the:

1. Effect of Science writing heuristics (SWH) approach on achievement of students in biology when compared with those taught using conventional method.

2. Effect due to gender on the achievement of male and female students in biology.
3. Interaction effect of teaching methods and gender on the students' achievement in biology.
4. Effect of Science writing heuristics (SWH) approach on science process skill acquisition of students in biology when compared with those taught using conventional method.
5. Effect due to gender on science process skill acquisition of male and female students in biology.
6. Interaction effect of teaching methods and gender on the students' science process skills acquisition in biology.

Significance of the Study

The findings of this study would be beneficial to biology teachers, secondary school biology students, curriculum planners, and the government.

The findings of this study would inform biology teachers who may consult this study on how to use science writing heuristics and the possible effects it can bear on the students' achievement and their acquisition of science process skills. Since the findings of this study validated a positive effect of SWH on achievement and science process skills acquisition, biology teachers will be spurred to use SWH in the classroom by adopting similar approach as used in this study.

The findings of this study would also make biology students to appreciate the value of SWH in the learning of biology concepts and acquisition of science process skills. The findings of the study could motivate the students to attempt to use SWH in the learning of science concepts, develop self-learning and self-direction.

Curriculum planners through the findings of this study will be informed of the benefits of SWH. They will be stimulated to review the strategies and activities included for every biology concept. They will be motivated through the findings of this study to include SWH among the students' activities in learning biology concepts.

The Ministry of Education through the findings of this study will come to be aware of the importance of SWH in the process of learning biology. They will be stimulated to provide templates for students' laboratory activities and learning.

Scope of the Study

This study was restricted to determining the effect of science writing heuristics approach on secondary school students' achievement and acquisition of science process skills in biology in Oshimili North Local Government Area of Delta state. In this study, the science process skills of observing, inferring, classifying, experimenting and communicating were investigated. The study is delimited to senior secondary school two (S.S. 2) biology students. The choice of the SS2 students is because they are intermediate learners who are neither new to biology concepts nor preparing for any external examination. The content areas covered are; stages of development in toad, germination of seeds, flower as an organ of reproduction in flowering plant and adaptation in xerophytes. The content areas were chosen because they are among the areas students have shown weaknesses in past external examinations. They are also part of the S.S.2 scheme of work and involve laboratory students' experiments. The content areas are therefore suitable for experimentation since students would have to write report on the experiments using science writing heuristics.

Research Questions

The following research questions guided this study:

1. What is the mean achievement scores of students taught biology using science writing heuristics (SWH) and those taught using conventional method?
2. What is the mean achievement scores of male and female students in biology?
3. What is the mean science process skill acquisition scores of students taught biology using science writing heuristics (SWH) and those taught using conventional method?
4. What is the mean science process skills acquisition scores of male and female students in biology?

Hypotheses

The following null hypotheses were tested at 0.05 level of significance.

1. There is no significant difference in the mean achievement scores of students taught biology using Science writing heuristics (SWH) and those taught using conventional method.
2. There is no significant difference between the mean achievement scores of male and female students.
3. There is no significant interaction effect of teaching methods and gender on the students' achievement in biology.
4. There is no significant difference in the mean science process skills acquisition scores of students taught biology using SWH and those taught using conventional method.
5. There is no significant difference between the mean SPS acquisition scores of male and female students.

6. There is no significant interaction effect of teaching methods and gender on the students' acquisition of science process skills in biology.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter contains a review of literature that is relevant to the present study and is presented under the following sub-headings:

Conceptual Framework

Science Writing Heuristics

Academic Achievement

Science process skills

Theoretical Framework

Constructivist theory of Bruner

Theoretical Studies

Differences between science writing heuristics (SWH) and conventional teaching Approach

SWH teaching approach and science process skills

Empirical Studies

Science writing heuristics (SWH) and achievement

SWH and acquisition of science process skill

Gender and effect of SWH on achievement and acquisition of science process skills

Summary of Literature Review

Conceptual Framework

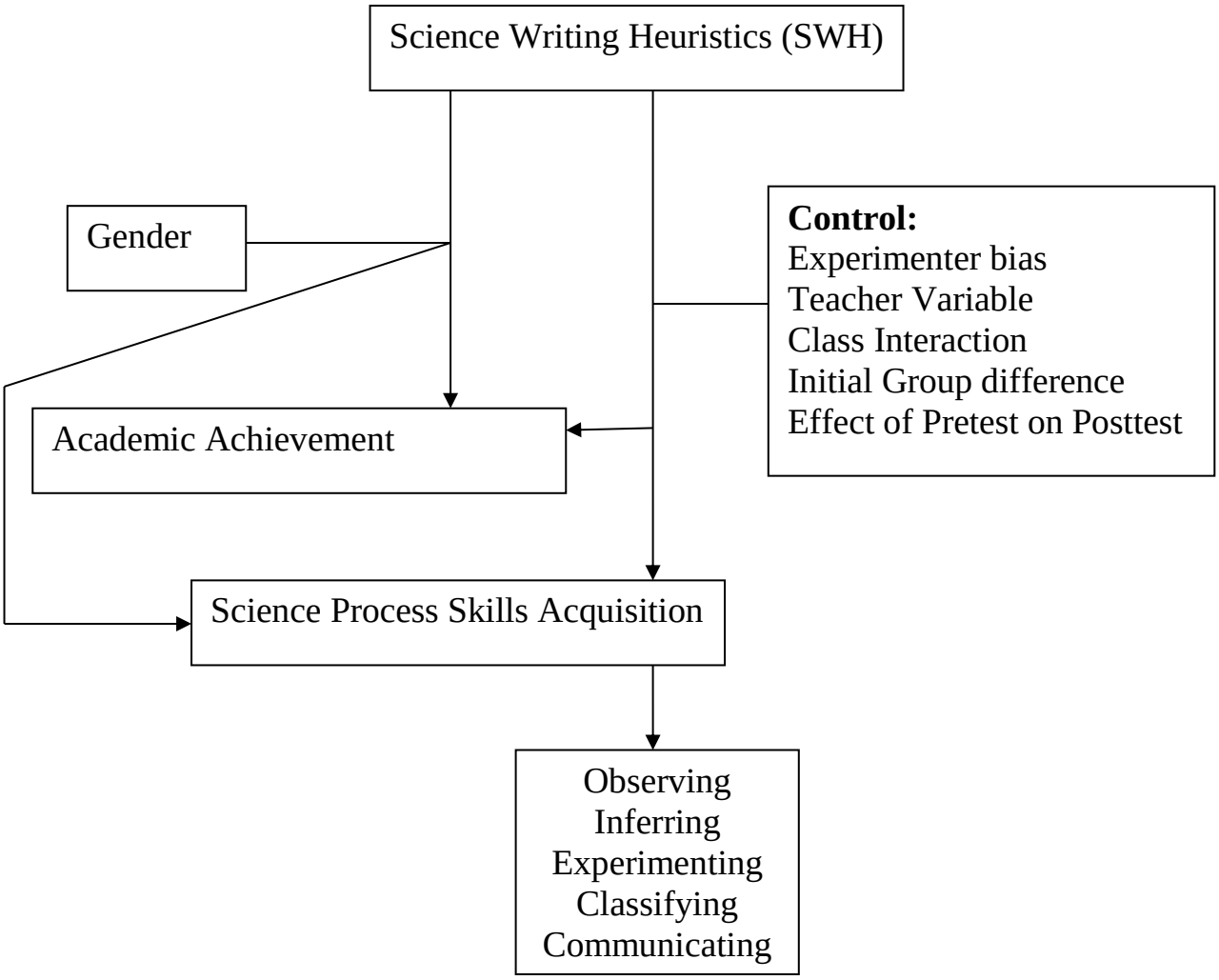


Figure 1: Schematic representation of the concept of the study

Science Writing Heuristics

Science writing heuristics (SWH) simply means teaching science and reporting scientific evidence through discovery (Erduran, 2014). SWH is used in the teaching of practical orientated topics in science; the students are put in place of independent discoverers with no help or guidance provided by the teachers. The method requires the teacher to set experimental problems for students' and then stands aside while the students'

discover the answers. Science writing heuristics (SWH) is a relatively new teaching approach in Nigeria. This approach can also help in the enhancement of scientific literacy in students' and teaching of biology and other science subjects in secondary schools.

In the Science writing heuristics classroom, the lesson begins with the students carrying out the experiments, using the questions and instructions (hints on the topic) on the SWH students' template as a guide, students' record their observations and findings, compares their report with that of their classmates and exchange ideas. The students' reports are analysed by the teacher to find out areas where the students' are having difficulties in understanding the concept being taught. From the teacher's observation of the students' difficulties, the teacher begins the lesson, making sure that emphases are made on the areas where students' are having difficulties. The model for science writing heurisitic teaching approach is shown in figure 1

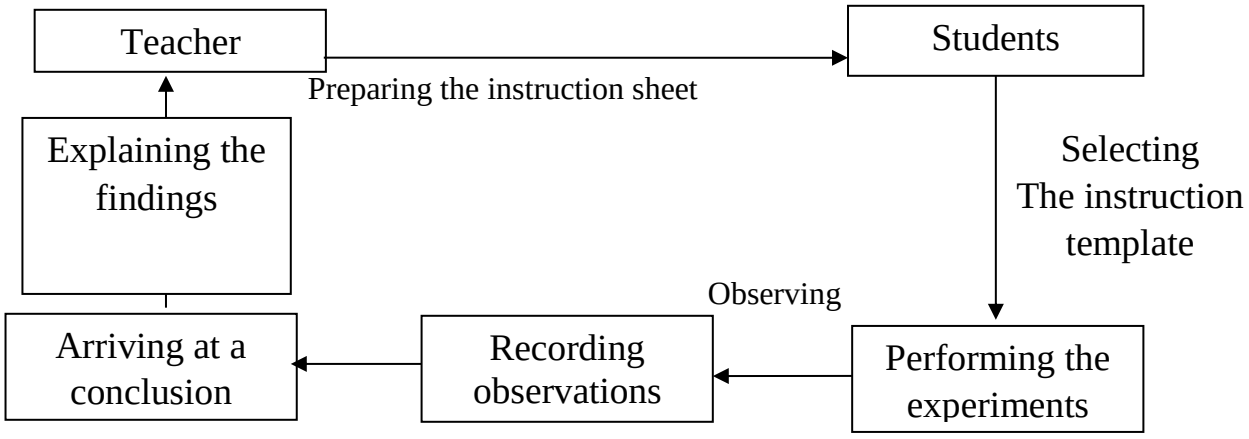


Figure 2: A Model of Science Writing Heuristics (SWH) Teaching Method (Developed by the researcher)

According to Drobitsky (2015), the SWH process begins with a discourse between the students and the teacher at the students' current level of understanding. This provides an avenue for scaffolding of knowledge by students and enabling the teacher to better

address the students' specific learning style and pre-knowledge. With carefully planned and guided prompting, students' questioning will occur naturally, leading students to want to find out or discover knowledge for themselves. If necessary, the teacher uses prompts to redirect students when they begin to go astray from the desired topic under discussion. Once the students have decided what they plan to investigate and frame their own questions, they will be more motivated to continue.

This process of experimentation helps the students to feel that they themselves are in control of their learning and are learning what they want to know. This active engagement in the learning process leads to increased conceptual understanding and acquisition of science process skill. As results of the experiments are been discussed and compared between students, there is an opportunity to shape students' understanding of the science concepts been taught. The mental processes occur in a students' mind as the student discusses and work out his or her reasoning as a result of the communication of ideas (Drobitsky, 2015).

Science writing heuristics incorporates writing as a learning tool than just a reporting tool, when utilizing this type of writing (writing-to-learn), students generate and clarify their understanding of scientific concepts for themselves rather than simply communicating with a teacher for evaluation (McDermitt, 2010). The active engagement in writing enables metacognition and increases conceptual understanding. These activities often require that students write for a specific audience, this may be their classmates, students in another content course or even younger students. Writing to an audience other than their teacher forces the students to express their thoughts clearly and coherently (Balgopal & Wallace, 2013).

Writing to learn can also benefit students when they peer-review and edit each others work, solve problems and clarify ideas to see what happens after carrying out an experiment. Editing another student's work is shown to improve a student's own writing skills. If the reader is unclear about something, they ask for clarification. The readers are free to make comments and suggestions, this process supports students, especially those with weaker writing skills, in creating a well-written and well-understood final report (Ende, 2012).

Biological science programs should aim at producing graduate and students who are able to think like a scientist, that is, students and graduates who are able to solve problems in multiple contexts and effectively integrate information into meaningful scientific concepts. This scientific literacy and science process skills should be impacted in the students as early as possible. A more effective way to help students master science concepts and acquire science process skills and better prepare them for careers in science would be through explicit instruction of science process skills, helping students acquire mastery and use of these skills early in the college curriculum and thereby augmenting their content acquisition and interdisciplinary ways of perception (Coil, Wenderoth, Cunningham, & Dirks, 2010). Thus, in this study science writing heuristics was used as a teaching approach and a tool for enhancing students' acquisition of science process skills in biology.

Academic Achievement

Achievement could be seen as something which was carried out successfully, it is a product of effort or series of efforts. Ozmon (2008) described achievement as something which has been accomplished successfully, especially by means of exertion, skill practice

or perseverance. Ozmon sees achievement as a test for the measurement and comparison of skills in various fields of academic study. Kingir, Gbeban and Gunel (2012) regards achievement as a change in behaviour exhibited at the end of a given period of time or within a given time range. Ozmon, (2009) explained that achievement involves the determination of the degree of attainment of individuals in tasks, courses or programmes of which the individuals were sufficiently exposed. Achievement tests result in academics have many functions which include: to enable us determine the relative position or rank of individual student with respect to their test performance. It also enables us to obtain information on the extent to which a student has attained the criterion performance. Students, teachers, parents and the entire society are much concerned about the academic achievement of students.

Academic achievement has to do with what a learner is able to accomplish by execution of class work in the school. Saribas and Bayram, (2009) sees academic achievement as something a learner do or achieve at school, college or university, in class, in a laboratory or field work. Suman, (2011) said that academic achievement refers to achievement of individuals' objective to various types of knowledge and skills. According to the author the objectives are established based on the age, prior learning and capacity of individuals with regards to education, socialization and qualification.

Academic achievement is systematic and purposeful quantification of learning outcomes. Some of the purposes of academic achievement measurement are enumerated by Mason and Boscolo (2000) as follows: to determine the relative effectiveness of a programme in terms of students' behavioural outputs, to identify students growth or lack of growth in acquiring desirable knowledge, skills, attitudes and social values; to help

teachers determine the effectiveness of their teaching technique and learning material, to help motivate students to learn as they discover their progress or lack of progress in a given task; to encourage students to develop a sense of discipline and systematic study habits; to acquaint parents or guardians with their children's performance; to predict the general trend in the development of teaching/learning process; to make reliable decision about education planning and to provide educational administrators with adequate information about teachers effectiveness and school need. Academic achievement is the extent of accomplishment of instructional objectives expressed in numerical form (scores) and obtained through achievement test.

Science Process Skills

Science process skills (SPS) are the skills used by scientists to create scientific knowledge, think about a problem and make conclusions about the problem (Karsili and Sahin, 2009). Mei, Kaling, Xingi, and Khoon, (2007) viewed science process skills (SPS) as a set of broadly transferable abilities that reflects what scientists do. According to National Policy on Education, science education programmes will be designed to enable the learner to acquire problem solving and decision making skills and to discover the relationship of science with health, agriculture, industry and other aspects of daily life (FRN, 2004). Generally, SPS are categorized into two groups: basic process skills and integrated process skills as follows.

The basic science process skills are the initial skills required for the learner to be able to partake actively in the classroom/laboratory activities during lessons, these skills include;

1. Observing - using the senses to gather information about an object or event. Example: Describing a pencil as yellow.
2. Inferring - making an "educated guess" about an object or event based on previously gathered data or information. Example: Saying that the person who used a pencil made a lot of mistakes because the eraser has worn out.
3. Measuring - using both standard and non-standard measures and estimates to describe the dimensions of an object or event. Example: Using a meter stick to measure the length of a table in centimeters.
4. Communicating - using words or graphic symbols to describe an action, object or event. Example: Describing the change in height of a plant over time in writing or through a graph.
5. Classifying - grouping or ordering objects or events into categories based on properties or criteria. Example: Placing all rocks having certain grain size or hardness into one group.
6. Predicting - stating the outcome of future event based on a pattern of evidence. Example: Predicting the height of a plant in two weeks' time based on a graph of its growth during the previous four results.

The complex science process skills are more difficult for learners to acquire. Only learners who have mastered the use of basic science process skills can effectively use it to solve complex scientific tasks. The complex science process skills include:

1. Controlling variables - being able to identify variables that can affect an experimental outcome, keeping most constant while manipulating only the independent variable. Example: Realizing through past experiences that the amount

of light and water needed to be controlled when testing to see how the addition of organic matter affects the growth of beans.

2. Defining operationally - stating how to measure a variable in an experiment. Example: Stating that bean growth will be measured in centimeters per week.
3. Formulating hypotheses - stating the expected outcome of an experiment. Example: The greater the amount of organic matter added to the soil, the greater the bean growth.
4. Interpreting data - organizing data and drawing conclusions from it. Example: Recording data from the experiment on bean growth in a data table and forming a conclusion which relates trends in the data to variables.
5. Experimenting - being able to conduct an experiment, including asking an appropriate question, stating a hypothesis, identifying and controlling variables, operationally defining those variables, designing a "fair" experiment, conducting the experiment, and interpreting the results of the experiment. Example: The entire process of conducting the experiment on the effects of organic matter on the growth of bean plants.
6. Formulating models - creating a mental or physical model of a process or event. Examples: The model of how the processes of evaporation and condensation interrelate in the water cycle.

According to Karamustafaoglu (2011), SPS are the skills used by scientists in their studies and reflects on the current behaviours of scientists when solving a problem and planning an experiment. Mutisya, Too and Rotich (2014) further indicate that science process skills are ways and methods used by scientists to access and process information.

Advocates of SPS acquisition at secondary school level of education indicated that these skills simplify learning of science, activate learners' sense of responsibility in their own learning as well as equip them with science research methods. It is therefore important that biology students in secondary schools are taught how to acquire scientific knowledge on their own through the use of SWH approach in teaching biology and other science subjects rather than learning scientific knowledge as concepts to be memorized and to pass examination.

Theoretical Framework

Constructivist theory by Bruner

Constructivist theory was propounded by Bruner in 1966. Bruner's constructivist theory states that, learning is an active process in which learners construct new ideas or concepts based upon their past knowledge. The learner selects and transforms information, constructs hypotheses, and makes decisions, relying on a cognitive structure to do so. Cognitive structure means an organization of experiences which allows the individual to go beyond the information given. Bruner (1966) argued that as far as instruction is concerned, the instructor should try and encourage students to discover principles by themselves. The instructor and students should engage in an active discussion. The task of the instructor is to translate information to be learned into a format appropriate to the learners' current state of understanding. Curriculum should be organized in a spiral manner so that the student continually builds upon what they have already learned.

Bruner (1966) states that a theory of instruction should address four major aspects in learning: (1) predisposition of the learner towards learning, (2) the ways in which the structure of knowledge can be organized so that it can be most readily grasped by the

learner, (3) the most effective sequences in which to present the learning material, and (4) the nature and placing of rewards and punishments. Effective methods for structuring knowledge should result in simplifying, generating new propositions, and increasing the manipulation of information. According to the constructivist view, the characteristics of individuals influence their learning as much as the teacher and school. This idea highlights the importance of students' prior knowledge for their subsequent learning. Students' prior conceptions originate from previous classes and personal experiences acquired from observation, experiments, television, internet and social settings. These conceptions may facilitate or hinder their further learning.

Implicit in Bruner's constructivist theory is that it supports SWH teaching approach which encourages students to be actively involved in their learning by experimenting and connecting prior experiences with new information. The learners choose information that allows them to construct hypotheses and make decisions, which gives the needed cognitive structure. Cognitive structure provides meaning and organization for their learning experiences and allows the individual to gain more than just the basic knowledge or vocabulary for the answering test questions and also master the use of science process skills. Furthermore, in the constructivist classroom, students work primarily in groups so that learning the required knowledge is interactive and dynamic. This type of classroom emphasizes social and communication skills because the students are expected to collaborate with one another and exchange ideas (Bruner, 1996). This is in line with the SWH teaching approach.

Theoretical Studies

Science Writing Heuristics; a deviation from traditional laboratory method

SWH is used in the teaching of practical orientated topics in science, the students are put in place of independent discoverers, thus, no help or guidance is provided by the teachers. According to Kingir (2011) heuristics method of teaching are methods which involve the teacher placing the students as far as possible in the attitude of the discoverer, methods which involve students finding out facts by themselves instead of being told about things. There are several gains to the use of science writing heuristics teaching approach in secondary school, SWH can help a student to solve problem by using scientific attitude, demonstrate the experiment, illustrates the results of the experiment, acquire knowledge about new science concepts, think independently, collects and analyze data for information and acquire basic and integrated science process skill. According to Drobitsky (2015) when students are required to list, describe or define, processes involved in writing, they are focused on concepts in isolation. However, when performing analytical tasks such as explaining real-world applications of scientific concepts, learners connect these into an integrated web of meaning.

When the students are involved in this type of discourse, they compare their findings with that of their peers. They can persuade others that what they are stating is factual and accurate. To think things through clearly, to examine what evidence supports a conclusion derived from experiments, based upon the students' generated hypothesis is a highly desirable skill that will aid in scientific knowledge and the acquisition of science process skills necessary for secondary school students to function as scientifically literate individuals (Kingir, 2011).

The conventional teaching method (traditional laboratory method) on the other hand do not reinforce science skills (measuring, using equipment, safety etc.) or teach the students how to work together for a common goal, without additional guiding questions. This format is not designed for the student to generate meaning of what occurred nor are the students expected to use their evidence to make a claim. The conventional laboratory write-up may require the students to make sense of their results, but more from the perspective of whether their result supported their hypothesis. The traditional laboratory write-up is compartmentalized: purpose, hypothesis, experimental design, data, and conclusion; the conclusion answering the question of whether their hypothesis was correct or not. This fails to make the laboratory experience personal for the students.

SWH, on the other hand, joins the discrete parts of the laboratory experiences together and makes the experience more personal and therefore a meaningful experiment. Instead of answering section headings (purpose, hypothesis, design, data, conclusion), the students develop their reports themselves (Drobitsky, 2015). Gunel, (2006) describes SWH as a tool that helps students construct a conceptual understanding of science topics through laboratory activities that are guided by templates; one template guides the teacher and the other guides the students (see Appendices H and I, page). Studies have shown that when students utilize SWH effectively, their construction of scientific meanings and conceptual understanding is improved (Gunel, Hand & Dermott, 2009, Handelsman, Miller & Fund, 2007).

The SWH process has several qualities which are supported by educational work and research based data. SWH uses collaborative learning and thus, has been found to support student achievement and acquisition of science process skills. The National

Science Teachers' Association (NSTA) recognizes the importance of social collaboration as they report that they expect science teachers to provide regular opportunities for students to collaborate effectively with others in carrying out complex tasks, share the work of the task, assume different roles at different times, and contribute and respond to ideas (NSTA, 2007). SWH arranges for students to interact frequently in smaller and more intimate groups. Having knowledge of the social and cognitive behaviours of the adolescent, the teacher can utilize SWH to assist these delicate students to work with their peers to build positive relationships and attitudes about learning science and acquisition of science process skills.

SWH teaching approach and science process skills

Science process skills can be developed by using SWH, inquiry, or investigative approach of teaching and learning science that gives students opportunities to practice these skills. Acquisition of science process skills can have a profound impact on student success in secondary science classes. Evidence shows that new students who participated in a course in which they were explicitly taught science process skills, out-performed students who did not participate in the program in subsequent introductory biology courses (Dirks & Cunningham, 2006).

Similarly, students in a molecular biology course who practiced data analysis, diagrammatic visualization, and other analytical reasoning skills had improved test scores compared with those in a control course. Explicit instruction in generating and interpreting scientific data and experiential research projects that promoted science process skills also benefited students' learning and reinforcement of course content (Yeoman & Zamorski, 2008). According to Kingir (2011), the SWH approach is grounded on the constructivist

philosophy because it encourages students to use guided inquiry laboratory activities and collaborative group work to actively negotiate and construct knowledge. SWH is not just a tool used for writing the laboratory reports but rather an argument-based inquiry because it successfully integrates inquiry activities, collaborative group work, meaning making via argumentation and writing-to-learn strategies. SWH bears the following advantages for science process skills acquisition:

a. The SWH format allows students' guided by the teacher to determine their own investigative questions.

b. Fosters within students an initial interest in the investigation and helps them develop scientific attitudes.

c. By asking their own questions, students assume ownership of their learning, which increases the chances of students' involvement in carrying out their own investigation.

d. Creates learning experiences that allows the students to learn about a concept in a way that is important to him or her.

e. Fosters the students writing skills and makes them psychologically sound, because SWH teaching approach is based on learning by doing.

f. Leads to acquisition of science process skills.

g. Helps students to improve on their studies, thereby leading to better achievement in biology.

i. It develops the habit of self-learning and self-directions in the students.

h. It fosters cordial relations between the students and the teacher and between students and their classmates.

Empirical Studies

The sub-heading deals with empirical studies that probed into science writing heuristics and its effect on students' achievement.

Science Writing Heuristics and Achievement

Brian (2004) investigated using Science Writing Heuristic to enhance learning outcomes from laboratory activities in seventh-grade science. The design of the study was the mixed-method quasi-experimental design. The population of the study comprised seventh grade students enrolled in an introductory biology course at a mid-Western Middle school between 1999 and 2000. The sample size for the study consisted of 93 students obtained purposively. The instruments for the study were Pre-test and Post-test named Pre Research Multiple-choice Questions (PMRQ) and Post Research Conceptual Questions (PRCQ) developed by the instructor and validated by experts. In this treatment, students used the SWH student templates to guide their written work for laboratory activity. To analyse the data obtained from the study, analysis of covariance was used. Results indicate those students who used the Science Writing Heuristic performed better as a group than students who did not, and that students who completed a textbook explanation as a write-up performed better as a group than those who completed a more traditional write-up format.

The researcher concluded that students' performance on conceptual questions on completion of the unit on cells was improved by engaging in a series of writing tasks. In particular, students who engaged the use of SWH and then completed a writing task as a means of summarizing their work outperformed students who used the normal traditional approach to laboratory work. The researcher recommended the use of SWH for teaching

biology by biology teachers. The researcher adopted similar approach in this study except that the biology students used were those in the secondary school level of education.

Mehmet, Mustafa and Erdogan (2010) conducted a study on the effect of implementation of science writing heuristic on students' achievement and attitudes toward laboratory in introductory physics laboratory. The purpose of the study was to evaluate the effect of implementing the Science Writing Heuristic (SWH) approach in the introductory physics laboratory and to learn students' views about the SWH. 3 research questions and 4 hypotheses guided the study. The mixed research design was used. The population of the study comprised first year science education students who attended introductory physics laboratory in a large university at the East of Turkey. The sample size for the study consisted of 42 freshmen students obtained randomly. The instrument for data collection was a 40 multiple choice test and 3 conception questions administered as pre-test and post-test validated by 2 professors and research assistants in physics. The method of data analysis was through the use of descriptive statistics and t-test. The result of the study indicated significant difference between control and treatment group in favour of the treatment group. Results of this study showed that the SWH approach increased students' mechanic unit achievement, conceptual understanding and attitude towards physics laboratory. According to analysis of the SWH student laboratory report template, 87.6% of the treatment group indicated that this report format developed their problem solving ability.

The study did not take into account the initial group difference among the students, thus, the use of pre-test. The present study used analysis of covariance and incorporated the students' pre-test in order to eliminate the initial group difference among the students. Also

the study was conducted with secondary school level biology students using template just as in the reviewed study.

Arnold, (2011) conducted a study on investigating the impact of the science writing heuristic on student learning in high school chemistry. The purpose of the study was to examined the effects of the use of the Science Writing Heuristic (SWH) on student learning in a high school chemistry classroom. Four research questions and 4 hypotheses guided that study. The design of the study was pre-test post-test quasi-experimental. The population of the study comprised 150, 000 Mid-Western high schools within the large cities. The sample size for the study consisted 72 students (50 females, 22 males) composed primarily of European-American students from predominantly middle-class background. The instrument for data collection was Pre-Science Reasoning Test which a standardized test from the 2010 practice Act of the schools and a teacher made test on gas laws. For experimentation students in the SWH group used template instead of the traditional worksheet format. The data obtained were analyzed using analysis of covariance. Results showed that there were no significant learning gains in the treatment group (SWH) as compared to the control group with regards to either conceptual understanding of the gas laws or in student scientific reasoning ability.

The study found no difference in the achievement of student in both the traditional and SWH groups. The finding of the study led to a mixed conclusion about the effect of SWH and the need for further studies in this area as the researcher recommended. In the present study however, senior secondary school year 2 students were used to examine the effect of SWH in biology achievement and also its effect on their acquisition of science

process skills of observing, experimenting, inferring, classifying and communicating was investigated.

Lori (2013) investigated the effect of incorporating the science writing heuristic approach to inquiry activities in a high school science classroom. The purpose of the study was to determine difference in achievement of students. When Science Writing Heuristic was used to provide students with a template for inquiry based activities and when students worked collaboratively on inquiry based activity and then wrote about the experiment they did including procedures, observations, data, and results using the SWH and when they did not. 4 research questions and 4 hypotheses guided the study. The design of the study was quasi-experimental. The population of the study comprised 38,000 students of sophomore level chemistry classes at Northglenn High School. The sample size for the study was 546 students. The instruments for data collection were pre-treatment and post-treatment survey, field notes, quizzes, journals, exams and laboratory reports.

In the treatment, the science writing heuristic approach (SWH) takes a lab or inquiry activity and makes it about the learning of the content by utilizing reading, writing, collaboration, and reflection. When using the SWH approach as a treatment within the classroom, labs and learning activities were completed using an inquiry based approach where students did the experiment or laboratory activity prior to learning the content utilizing the SWH template. The data analysis was done quantitatively and qualitatively; the data analysis was broken up into different components, student surveys, field notes, reflective journals, and quantitative data from exams, quizzes, and lab reports.

The results of the study from the data that were analyzed in regards to quiz scores and lab scores did not demonstrate that the SWH approach had an impact on student

grades. Period one grades on quizzes dropped from an average of 7.6 to 6.2, period three and period seven had no significant change. The lab reports demonstrated a drop in average lab report grades (average of 18 to 11), but during the treatment phase there was an increase of five students who did not turn in a lab report and these grades count as zeros in the grade book. The exam grade data demonstrate that SWH approach might have contributed to an increase in grades (11-13% increase pre-treatment to treatment). The researcher recommended that further studies be conducted in this area. In line with this recommendation the present study sought to investigate the effect of SWH using biology SS2 students, determining difference in achievement and acquisition of science process skills. The study made use of surveys, field notes, reflective journals, and quantitative data from exams, quizzes, and lab reports for data collection, in this present study, data were collected through standardized instrument of achievement test and science process skills template focused on observing, inferring, experimenting, classifying and communicating.

Amal, Sozan and Olfat (2015) carried out a study on the impact of the science writing heuristic on 10th grade chemistry students' achievement and attitude towards chemistry. The purpose of the study was to examine the effect of science writing heuristics on achievement of 10th grade chemistry students in properties and changes in matter. Two research questions and six hypotheses guided the study. The design of the study was pre-test post-test non-equivalent control group design. The population of the study was all 10^{th} grade chemistry students in Saudi Arabia. The sample size for the study consisted 90 10^{th} grade chemistry students obtained using multistage sampling.

The instruments for data collection were Chemistry Achievement Test (CAT) and Attitude Towards Chemistry (ATC) validated by lecturers in chemistry. The reliability of

the instruments was determined using Kudder-Richardson for the CAT and Cronbach's Alpha for the ATC. The coefficient of internal consistency yielded 0.76 and 0.82 for the CAT and ATC respectively. The data obtained were analyzed using t-test. The results of the analysis revealed that there was no significant difference between the mean scores of experimental and control groups in the CAT. There was significant difference between the mean scores of experimental and control groups in essay questions in favour of the experimental group. The study concluded that SWH is effective and recommended that workshops and training sessions should be done for science teachers on the SWH strategy to be able to help their future students to write SWH reports that reflect their scientific knowledge

Although, Amal et al.'s study made use of pre-test, the choice of analytical tool t-test did not take into account the initial group difference among the students. This led to doubt in the validity of the results of the study. In this present study, analysis of covariance was used to remove initial difference among the students so that only the actual effect of the treatment with SWH was determined. Apart from these, the study adopted similar method in investigating the effect of SWH on SS2 biology students' achievement instead of chemistry in Delta State Nigeria, instead of Saudi Arabia.

Science Writing Heuristics and Acquisition of Science Process Skill

Tseng (2014) conducted a study on the effects of the science writing heuristic (SWH) approach versus traditional instruction on yearly critical thinking gain scores in grade 5-8 classroom. The purpose of the study was to examine the possible effects of the Science Writing Heuristic (SWH) approach, an immersion argument-based inquiry approach to learning science, on students' critical thinking skills. 3 research questions and

3 hypotheses guided the study. The design of the study is quasi-experimental. The population of the study comprised 4,500 elementary and/or secondary school science classroom in public schools of the Midwest in the USA. The sample for the study included 4,417 students. The instrument for the study is a Critical Thinking Assessment which is a yearly critical thinking gain scores, as measured by Form X of Cornell Critical Thinking Test (CCTT-X), were compared for students who experienced the SWH approach versus students who experienced traditional instruction in both elementary (5th grade) and secondary schools (6th-8th grades). Reliability information reported in the manual includes both KR-21 and Spearman Brown, with KR-21 coefficients ranging from .55-.83 and split half coefficients ranging from .71-.90. Students yearly CCTT-X gain scores (post-test - pre-test) were used as the main dependent variable. Post-test and pre-test scores were derived by counting the total number of correct responses.

The results of the analyses of yearly gain scores for data sets that represented a single year of implementation yielded statistically significant differences favouring SWH over traditional instruction in all instances and statistically significant interactions between gender and grade level in most instances. The interactions revealed that females had higher gain scores than males at lower grade levels but the reverse was true at higher grade levels. Analyses from data sets that included two years of implementation revealed higher overall gains for SWH instruction than for traditional instruction but most of those gains were achieved during the first year of implementation. The researcher recommended from the results that teachers should adopt SWH in teaching critical thinking skills in science classrooms.

Gender and effect of SWH on achievement and acquisition of science process skills

Chin-Mei (2014) investigate the effects of the science writing heuristics (SWH) approach versus traditional instruction on yearly critical thinking gain scores in grade 5-8 classrooms. The purpose of the study was to examine the possible effects of the Science Writing Heuristic (SWH) approach, an immersion argument-based inquiry approach to learning science, on students' critical thinking skills. The design of the study was experimental. The population of the study was 4500 students of secondary school science classrooms in public schools of Midwest in the USA. Total sample for the study was 594 in the treatment group and 544 in the control group. The instruments for the study were Cornell Critical Thinling Test with a reliability of .55-.83 established using KR-21, Spearman Brown and split half. Guided by a question-claims evidence structure, students who participated in SWH approach were required to negotiate meaning and construct arguments using writing as a tool throughout the scientific investigation process. Students in the control groups learned science in traditional classroom settings.

Data from five data sets that included 4417 students were analyzed cross-sectionally and longitudinally. Yearly critical thinking gain scores, as measured by Form X of Cornell Critical Thinking Test, were compared for students who experienced the SWH approach versus students who experienced traditional instruction in both elementary (5th grade) and secondary schools (6th-8th grades). Analyses of yearly gain scores for data sets that represented a single year of implementation yielded statistically significant differences favoring SWH over traditional instruction in all instances and statistically significant interactions between gender and grade level in most instances. The interactions revealed that females had higher gain scores than males at lower grade levels but the reverse was

true at higher grade levels. Analyses from data sets that included two years of implementation revealed higher overall gains for SWH instruction than for traditional instruction but most of those gains were achieved during the first year of implementation. The difference between the reviewed study and the current study is that the current study focused on the process skills of observing, experimenting, inferring, classifying and communication. It did not examine critical thinking. Also, the data used in the study was gather over a month treatment unlike in the review study where longitudal data from students were analysed.

Summary of Review of Related Literature

The study reviewed literatures under conceptual framework, theoretical framework, theoretical studies and empirical studies. The conceptual framework reviewed the concepts of science writing heuristics (SWH), achievement, academic achievement and science process skills. Science writing heuristics simply means teaching science and reporting scientific evidence through discovery. Achievement describes something which has been accomplished successfully, especially by means of exertion, skill practice or perseverance. Academic achievement has to do with what a learner is able to accomplish by execution of class work in the school. Science process skills (SPS) is conceptualized as a set of broadly transferable abilities that reflects what scientists do.

The theoretical framework examined and which anchored the study was the constructivist theory of Bruner. Bruner's constructivist theory states that learning is an active process in which learners construct new ideas or concepts based upon their current/past knowledge. Implicit in Bruner's constructivist theory is the support of SWH

teaching approach which encourages students to be actively involved in their learning by experimenting and connecting prior experiences with new information.

The theoretical studies related the differences between science writing heuristics and conventional teaching approach. It also examined SWH teaching approach and science process skills. The empirical studies were reviewed under studies on science writing heuristics and achievement, and studies on science writing heuristics and acquisition of science process skills.

From the studies reviewed it was noted that most of the studies were conducted at university level and primary level of education. The studies did not probe into the effect of SWH based on gender. All the studies reviewed were conducted abroad and on varied subject areas. The most obvious gap from the empirical studies is that the result of studies on the effect of SWH is inconclusive. Some of the studies indicated a significant difference in the achievement of students in favour of SWH while other's indicated no significant difference in achievement when compared to the traditional or conventional teaching method. None of such studies to the researcher’s knowledge has been conducted in the subject area of biology in Oshimili North local government area of Delta state. These gaps noted in the study were what the present study went about to fill. Also, only one study probed into the effect of SWH on acquisition of science process skills with focus only on critical thinking skill. This study however, examined the effect of SWH on the science process skills of observing, inferring, experimenting, classifying and communicating.

CHAPTER THREE

METHOD

This chapter presents a description of the procedures that was used in carrying out this study. The chapter is organized under the following sub-headings: research design, area of the study, population of the study, sample and sampling techniques, instrument for data collection, validation of the instruments, reliability of instrument, method of data collection and method of data analysis.

Research Design:

The design of this study is quasi-experimental, specifically the non-equivalent control group design. According to Nworgu (2015), quasi- experiment is an experiment where random assignment of subjects to experimental and control groups is not possible. The design was therefore adopted for the study because variables were manipulated within intact or pre-existing groups. The design is summarized below.

$$\begin{array}{ccc} 0_1 & X & 0_2 \\ \hline 0_1 & \sim X & 0_2 \end{array}$$

Figure 3: Design of the Study

Where,

E = Experimental Group

C = Control group

0_1 = Pre-test

0_2 = Post-test

X = Treatment with SWH

~X = Treatment with Conventional method

Area of the Study

The study was carried out in Oshimili North Local Government Area of Delta State. Oshimili North is one of the twenty-five Local Government Areas that make up Delta State, South-South geo-Political region of Nigeria. The Local Government was created in 1997 and until its creation, was part of the old Oshimili Local Government Area. The Local Government is headquartered at Akwukwu-Igbo and comprises prominent towns such as Ugbolu, Ukala, Ibusa, Illah and Okpanam. The people of this local government area speak Igbo, which the Igbo indigenes refer to as the Enuani dialect of Igbo language. The people of Oshimili North are mostly farmers with steady and ready markets for their produce. There are nine government co-educational and two single-sex secondary schools in Oshimili North Local Government Area. This area is considered appropriate for the study because it is a riverine area, the inhabitants of this area are mostly farmers, fishermen and business people, with very few civil servants. The researcher believes that the study in this area could help equip teachers and students of biology with teaching and learning tools that could help improve achievement in biology.

Population of the Study

The population of the study comprised 1,946 senior secondary school year two (SS 2) biology students in 11 secondary schools in Oshimili North Local Government Area in Delta state. (Source: Ministry of Education, Asaba, 2017). There are nine co-educational schools and two single sex schools (see Appendix A, p. 66 for list of school).

Sample and Sampling Techniques

The sample for the study is 207 SS2 students. Only co-educational schools were used for the study and this is because majority of the schools in the area of the study were

coeducational. From the nine co-educational schools in Oshimilli North local government area, purposive sampling was used to select two schools which were not closely located. This is to take care of class interaction of subjects, an extraneous variable that may affect the outcome of the study should the subjects from the experimental and control groups interact. The schools were randomly assigned to experimental and control conditions. In each of the schools, biology students were used. The experimental group comprised 101 students (50 males and 51 females) while the control group comprised 106 students (56 males and 50 females).

Instruments for Data Collection

The instruments for the study were Biology Achievement Test (BAT) and Science Process Skills Acquisition Test (SPSAT) developed by the researcher. BAT is a 25-item multiple choice objective test (see Appendix B, p. 67 for details on BAT) based on 4 concepts in S.S 2 biology curriculum. The questions were taken from standardized West Africa Examination (WAEC) past questions using a table of specifications (see Appendix C, p. 70 for table of specification).

SPSAT consisted of four practical biology questions with a template developed by the researcher in the content areas taught which was used to evaluate the students' acquisition of the science process skills of observing, inferring, experimenting and communicating. The questions in SPSAT probed the student's ability to carry out simple laboratory experiments and using science writing heuristics through writing on the templates to give an indication of their level of acquisition of science process skills (see Appendix D, p. 71 for details on SPSAT). A table of specification was used to determine the areas and skills measured (see Appendix E, p. 76 table of specification on SPSAT).

Lesson plan was developed for the experimental and control group teachers by the researcher in the content areas taught (see Appendix F, p. 77 for lesson plans).

Validation of the Instrument

Since the Biology Achievement Test (BAT) questions were guided by a table of specification and obtained from an question from a formal examination body WAEC, the instrument was given to a lecturer in the department of science education for validation. However, the initial draft of the SPSAT, the objectives of the study, research questions, hypotheses and lesson plans were given to two lecturers from the Departments of Science Education and one lecturer from the Department of Educational Foundations, Nnamdi Azikiwe University, Awka and one experienced Biology teacher in the secondary school. Validators' were requested to validate the SPSAT in-terms of the suitability of the items for the students, clarity of the language and content coverage and any other considerations The corrections and suggestions of the validators were incorporated into the final production of the instrument.

Reliability of the Instrument

The reliability of the BAT and SPSAT instrument was established using Kudder-Richardson 20 (KR-20) formula. The rationale behind the use of KR-20 method is that it is appropriate for objective test items that are dichotomously scored. KR-20 was chosen because the difficulty levels of the question items is heterogeneous. Thus, the students will face varied level of challenges in attempting the questions. The instrument was administered to 40 biology students outside the area of study and the obtained scores were tested for reliability using the KR-20 formula. The coefficient of internal consistency

obtained for BAT is 0.91 (Appendix G, pg. 138) and that of the SPSAT is 0.83 (Appendix H, pg. 140).

Experimental Procedure

Training of Research Assistants

Before the experiment, the treatment and control groups were given pre-test. This was done through the help of the regular classroom biology teachers who were trained as research assistants.

The training program before the treatment process commenced, involved two biology teachers selected from the experimental school. They were trained on how to use the science writing heuristics teaching approach. The training of the research assistants for the study lasted for one week (two hours each day for three days). The training programme is as contained in Appendix I, page 142.

Pretesting: Before the experiment commenced, the BAT and SPSAT were administered to the students as Pre-tests to obtain the students' prior knowledge on the content areas to be taught. They were given no feedback on their achievement in the pre-test in order to reduce test knowledge in the post-test.

Teaching of students/ participants: Immediately after the pretest, treatment began. The experimental group was taught the biology concepts using Science Writing Heuristic instructional method, while the control group was taught the same topics using the conventional method for a period of four weeks. The research assistants carried out the experiment in the experimental group as follows:

Week 1: In week one, the students were exposed to the topic: stages of development of a toad. The students were provided with SWH students' templates, live specimen of tadpoles

and a toad. Before the lesson, the students were requested to locate pool of stagnant waters and ensure they observe the water for stages in the development of a toad. During the treatment, the students were taken to the laboratory and were requested to solve problems in the template relative to experiments on the stages of the development of a toad. Students were requested to brain storm and try to report exactly what they observe both in the habitat and from the laboratory specimen. After writing their reports, students were requested to exchange their templates with other students so as to compare and learn from each other. Thereafter, the teacher gave explanations on the stages of the development of a toad. After explanation, the teacher inspected the students' SWH reports and from the weakness observed, the teacher gave a summary on the important points of the lesson highlighting the areas where the students showed weaknesses.

Week 2: In the second week, the topic germination of seeds was treated. The students before the lesson were asked to plant different kinds of seeds with good soil and manure. Students were also told to monitor the growth of the seed and write down their day to day observations. To commence the lesson, the teacher questioned the students on concepts relating to germination of seed. The students then using the templates attempted SWH on the topic. The teacher to facilitate interaction among students, called for explanation from students from their templates about ideas relating to germination of seeds. The students then carry out experiments with the provided apparatus and report further on their templates. Students exchanged their templates and have the teacher evaluate the reports. The teacher then offered summary on important points based on students' weaknesses.

Week 3: the concept of flower as an organ of reproduction in flowering plant was treated. The students were provided with dissecting kits, flower from different plants such as

hibiscus flower, pride of Barbados, ixora flower and chart showing a transverse section of a hibiscus flower. The teacher explained the contents relating to flower. The students on their part observed the specimen and identified all the parts of the flowers, identified the type of ovary in the specimen, type of flower given to them as specimen, and observed the ovules of the specimen on their own and reported their observations where necessary. The students towards the end of the lesson exchanged their templates, and had the teacher evaluate their exercise. The teacher gave summary on the areas of weaknesses in the lesson.

Week 4: Here adaptation in Xerophytes was treated. For the experiment, students were provided with live specimen of cactus of prickly pear (opontia specie), aloe-vera, Christmas cactus, and dissecting kit. The students observed the specimen on their work station and used the results of their finding to answer questions on their SWH template. As the teacher offered explanation for the lesson, students paid attention and further observed the specimen placed before them, while they try to compare the report of their findings with the teacher's explanation. After explanations from the teacher, students dissected the specimen to observe the succulent stems, waxy cuticles and compared their observations with the teachers' explanation writing down their observation to further build their reports on the experiment. They exchanged their report with their classmates to observe the difference in their report.

The control group was taught the same concepts using conventional teaching method. The students were taught with the teacher modelling the experiment for the students after which the students were grouped together with a group head. The group head

conducted the experiment on behalf of the students and all the students wrote their individual reports. They were all given post-test after the experiment.

Control of Extraneous Variables

1. Experimenter bias: the treatment was administered by the regular biology teachers in the respective schools to avoid experimenter bias. They were trained as research assistants in the use of the instructional method before teaching the experimental group students. The researcher also made sure that the groups receive their respective treatments and were taught the same subject matter contents so that each group remained comparable to the other.

2. Teacher variable: The researcher prepared the instructional materials and ensured the lesson contents were the same. The teachers (two) used for the teaching of experimental group were adequately trained in the use of the lesson packages and asked to do a mock teaching to ensure that they have mastered the strategy to be used.

3. Class interaction: The schools used in the study are all situated some distances away from each other in two different towns to avoid subject interaction.

4. Initial group difference: Analysis of covariance (ANCOVA) was used to remove the initial group differences among the students used in the study.

5. Effect of Pre-test on Post-test: The lesson package lasted for four weeks and the post-test administered in the sixth week. The duration of the lesson and the reshuffling of the BAT items took care of the effect of pre-test on post-test. Also, the colour of the paper used in the post-test was made different from the one used in the pre-test.

Method of Data Collection

The instruments were administered as pretest before the treatment and posttest after the treatment. The data obtained from the study were collated and analysed in line with research questions and hypotheses. The BAT is a 25 item multiple choice objective questions with four options lettered A to D. Each correct response is scored 4 marks and 100 marks in total. The Science Process Skills Acquisition Test (SPSAT) has four practical questions, each question carries ten marks which will yield a total score of 40 marks. The scores will be converted to 100 percent by multiplying the students' score in the test with 100 and dividing with 40.

Method of Data Analysis

The research questions were answered using mean. The hypotheses were tested using analysis of covariance (ANCOVA). ANCOVA was used because it helped to take care of the initial differences among groups. The decision rule is as follows: For the hypotheses, reject null hypothesis when P-value is less than (<) 0.05, otherwise do not reject the null hypothesis.

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF DATA

This chapter deals with the analysis of data obtained by administering the research instruments. The results are presented in two sections, the section that answers the research question and the section that tests the hypotheses.

Research Question 1: What is the mean achievement scores of students taught biology using science writing heuristics (SWH) and those taught using conventional method?

Table 1: Pretest and Posttest Mean Achievement Scores of Students taught Biology using SWH and those taught Conventional Method

Source of Variation	N	Pretest Mean	Posttest Mean	Gained Mean	Pretest SD	Posttest SD
SWH	101	20.35	60.29	39.94	7.32	7.55
Conventional	106	20.71	35.09	14.38	7.35	6.55

Table 1 shows that the group taught using science writing heuristics (SWH) had gained mean achievement score of 39.94 and the group taught using conventional method had mean gain score of 14.38. The spread of scores was higher in the group taught with SWH than the group taught using conventional method.

Research Question 2: What is the mean achievement scores of male and female students in biology?

Table 2: Pretest and Posttest Mean of Achievement Scores of Male and Female Students in Biology

Group	Gender	N	Pretest mean	Posttest mean	Gained Mean	Pretest SD	Posttest SD
SWH	Male	50	21.18	59.78	38.60	7.18	7.57
	Female	51	19.50	60.80	41.30	7.44	7.58
Conventional	Male	56	21.27	35.49	14.22	7.61	6.58
	Female	50	20.18	34.73	14.55	7.13	6.56

Table 2 shows that male students taught using science writing heuristics (SWH) had gained mean achievement score of 38.60 and female had mean gained score of 41.30. Male students taught using conventional method had gained mean achievement score of 14.22 and females had mean gained score of 14.55. The use of SWH increased the spread of scores among the females than it did among the male students in the SWH group but the reverse was the case of students in the conventional group.

Research Question 3: What is the mean science process skill acquisition scores of students taught biology using science writing heuristics (SWH) and those taught using conventional method?

Table 3: Pretest and Posttest Mean of SPS Scores of Students taught Biology using SWH and those taught using Conventional Method

Source of Variation	N	Pretest Mean	Posttest Mean	Gained Mean	Pretest SD	Posttest SD
SWH	101	21.02	58.39	37.37	4.10	9.39
Conventional	106	20.56	35.69	15.13	4.01	4.53

Table 3 shows that the students exposed to SWH had overall gain in mean science process skill score of 37.37 while those exposed to conventional method had overall gain in mean score of 15.13. SWH increased the spread of SPS scores much more than the use of conventional method did.

Research Question: What is the mean science process skills acquisition scores of male and female students in biology?

Table 4: Mean of SPS Scores of Male and Female Students in Biology

Group	Gender	N	Pretest mean	Posttest mean	Gained Mean	Pretest SD	Posttest SD
SWH	Male	51	20.57	57.24	36.67	3.26	9.13
	Female	50	21.48	59.56	38.08	4.79	9.60
Conventional	Male	56	20.51	35.96	15.45	4.08	4.92
	Female	50	20.60	35.44	14.84	3.99	4.17

Table 4 shows that the male students exposed to SWH had gain in mean science process skill score of 36.67 while the female students had gain mean score of 38.08. The male students exposed to conventional method had gain in mean science process skill score of 15.45 while the female students had gain mean score of 14.84. SWH increased the spread of SPS scores among both the male and female students.

Hypothesis 1: There is no significant difference in the mean achievement scores of students taught biology using Science writing heuristics (SWH) and those taught using conventional method.

Table 5: ANCOVA on Effect of SWH on Achievement of Students in Biology and those taught using Conventional Method

Source of variation	SS	df	MS	F	Sig.	Decision
Corrected Model	32868.826[a]	4	8217.206	163.337	.000	
Intercept	51810.552	1	51810.552	1029.863	.000	
Pretest	2.025	1	2.025	.040	.841	
Gender	41.222	1	41.222	.819	.366	NS
Method	32766.762	1	32766.762	651.321	.000	S
Gender * Method	1.080	1	1.080	.021	.884	NS
Error	10162.256	202	50.308			
Total	507845.000	207				
Corrected Total	43031.082	206				

Table 5 shows that there was significant mean effect of the treatment on the achievement scores of the students, F (1, 206) = 651.321, P = 0.000 <0.05. Thus, the null hypothesis was rejected. Therefore, effect of science writing heuristics (SWH) approach on achievement of students in biology is significant when compared with those taught using conventional method using their pretest and posttest mean scores

Hypothesis 2: There is no significant difference between the mean achievement scores of male and female students.

Table 5 also shows that there was no significant mean effect of the treatment on the achievement scores of the male and female students, F (1, 206) = .819, P = 0.366 >0.05. Thus, null hypothesis was not rejected. Therefore, there is no significant difference between the mean achievement scores of male and female students.

Hypothesis 3: There is no significant interaction effect of teaching methods and gender on the students' achievement in biology.

Table 5 further reveals that there was no significant interaction between gender and teaching methods as on achievement scores of students, F (1, 206) = 0.021, P= 0.884 > 0.05. Therefore, the null hypothesis was not rejected. There is no significant interaction effect of teaching methods and gender on the students' achievement in biology.

Hypothesis 4: There is no significant difference in the mean science process skills acquisition scores of students taught biology using SWH and those taught using conventional method.

Table 6: ANCOVA on Effect of SWH on SPS Acquisition of Students in Biology and those taught using Conventional Method

Source of variation	SS	df	MS	F	Sig.	Decision
Corrected Model	26925.275[a]	4	6731.319	128.008	.000	
Intercept	16927.627	1	16927.627	321.909	.000	
Pretest	2.256	1	2.256	.043	.836	
Gender	88.080	1	88.080	1.675	.197	NS
Method	26726.283	1	26726.283	508.248	.000	S
Gender * Method	31.733	1	31.733	.603	.438	NS
Error	10622.203	202	52.585			
Total	490871.000	207				
Corrected Total	37547.478	206				

Table 6 shows that there was a significant mean effect of the treatment on the mean scores in science process skills of the students, F (1, 206) = 508.248, P (0.000) <0.05. Thus, the null hypothesis was rejected. Therefore, there is significant difference in the mean achievement scores of students taught using SWH and those taught using conventional method.

Hypothesis 5: There is no significant difference between the mean SPS acquisition scores of male and female students.

Table 6 also shows that there was no significant mean effect of the treatment on the mean SPS acquisition scores of the male and female students, F (1, 206) = 1.675, P = .197 >0.05. Thus, null hypothesis was not rejected. Therefore, there is no significant difference between the mean SPS acquisition scores of male and female students.

Hypothesis 6: There is no significant interaction effect of teaching methods and gender on the students' acquisition of science process skills in biology.

Table 6 further reveals that there was no significant interaction between gender and teaching methods as on SPS acquisition scores of students, F (1, 206) = .603, P= 0.438 > 0.05. Therefore, the null hypothesis was not rejected. There is no significant interaction effect of teaching methods and gender on the students' SPS acquisition scores in biology.

Summary of Major Findings

1. There is significant difference in the mean achievement scores of students taught biology using Science writing heuristics (SWH) approach and those taught using conventional method.
2. There is no significant difference in the achievement of male and female students in biology.

3. There is no significant interaction effect of teaching methods and gender on the students' achievement in biology.
4. There is significant difference in the mean science process skill acquisition scores of students taught biology using Science writing heuristics (SWH) approach and those taught using conventional method.
5. There is no significant difference in the mean science process skill acquisition scores of male and female students in biology.
6. There is no significant interaction effect of teaching methods and gender on mean science process skills scores.

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

This chapter discussed the results of the study, the conclusions from the study, and the recommendations made from the findings of the study. Also, the educational implications of the study and suggestions for further studies were presented in this chapter.

Discussion of Findings

The discussion of findings is organized under the following sub-headings:

- Effect of science writing heuristics (SWH) on students' achievement in biology
- Effect of SWH on students' acquisition of science process skills in biology
- Effectiveness of SWH on achievement and science process skills acquisition of male and female students in biology

Effect of Science Writing Heuristics (SWH) on Students' Achievement in Biology

The findings of this study revealed that SWH significantly enhanced the achievement of students in biology when compared to the conventional method using their pretest posttest scores. The significant difference in the gain in mean score of both groups in favour of SWH can be explained from the continuous interaction with the learning material inherent in SWH especially the use of students' templates. The heuristic templates which were designed around some questions prompted the students to utilize scientific thinking and reasoning through critically analyzing their prior knowledge, negotiating their own meaning of scientific concepts, developing links between claims and evidence, and constructing explanations that are based on relationships or generalizations observed.

This interaction helped the students to develop a deeper understanding of the big ideas of science contents through the phases of the students' template/plan. Also the

templates used by students required the students to solve a number of problems experimentally; the experiment starting with questions in other to find answer and a writing task, which often follows a continuous cycle of negotiating and clarifying meanings and explanations with their peers and teachers. This experience allowed the students to also compare their ideas with others and considering how their ideas changed in the process gave them a proper understanding of the concepts taught.

The collaborative nature found in the use of SWH is not common with the conventional method. The students do not engage much often in the experiment themselves and are not challenged by experimental tasks like in the use of SWH. In science writing heuristics group, the lessons began with the students carrying out the experiments, using the questions and instructions (hints on the topic) on the SWH students' template as a guide, students' record their observations and findings, compared their report with that of their classmates and exchanged ideas. This as Drobitsky (2015) noted provides an avenue for scaffolding of knowledge by students and enabling the teacher to better address the students' specific learning style and previous knowledge. With the carefully planned and guided prompting in the students' templates, students' questioning occurring naturally, lead students to want to find out or discover knowledge for themselves. Also, the experimentation made students to see themselves as being in control of their learning and are learning what they want to know. Drobitsky (2015) reported that the mental processes going on in students' mind as the students discussed and worked out their reasoning results in the communication of ideas. The active engagement in writing enables metacognition and increases conceptual understanding (McDermitt, 2010).

Writing to learn through the use of SWH templates also benefit students when they peer-review and edit each other's work, solve problems and clarify ideas to see what happens after carrying out an experiment. Editing another student's work helped to improve a student's own writing skills. It was observed that when a student is unclear about something, they ask for clarification. They are free to make comments and suggestions. This process Ende (2012) noted supports students, especially those with weaker writing skills, in creating a well-written and well-understood final report. SWH joins the discrete parts of the laboratory experiences together and made the experience more personal for each student and therefore a meaningful experiment. Instead of answering section headings (purpose, hypothesis, design, data, conclusion), the students develop their reports themselves.

The findings of this study supports the findings of Amal, Sozan, and Olfat (2015) who reported that students taught using SWH performed better than those taught using the conventional method and concluded from their study that SWH is effective. The findings of this study also supported that of Brian (2004) who investigated using Science Writing Heuristic to enhance learning outcomes from laboratory activities in seventh-grade science. Brian indicated those students who used the Science Writing Heuristic performed better as a group than students who did not, and that students who completed a textbook explanation as a write-up performed better as a group than those who completed a more traditional write-up format. The findings of the study however contradict that of Lori (2013) who investigated the effect of incorporating the science writing heuristic approach to inquiry activities in a high school science classroom. Lori reported that the results from the data that was analyzed in regards to quiz scores and lab scores did not demonstrate that the

SWH approach had an impact on student grades. The findings of the study also contradicted that of Arnold (2011) who conducted a study on investigating the impact of the science writing heuristic on student learning in high school chemistry. Arnold found no difference in the achievement of student in both the traditional and SWH groups.

Effect of SWH on Students' Acquisition Process Skills in biology

The results of the study also revealed that SWH significantly improved students' acquisition of science process skills of observing, experimenting, inferring, classifying and communicating, when compared to those taught using SWH. The students taught using SWH had higher mean gain scores in science process skills of observing, experimenting, inferring, classifying and communicating than those taught using the conventional method. There was also a significant difference in the overall mean scores of students in the science process skills of those taught biology using science writing heuristics (SWH) teaching approach and those taught using the conventional method. The overall mean gain score in science process skill acquisition revealed that students in SWH had a mean gain score of 25.70 and those in the conventional group had an overall mean gain score of 15.13.

The significant difference in the acquired skills of both group expressed by the significant difference in their mean science process skills acquisition scores is explained by the fact that the SWH templates are a learning tool rather than just a reporting tool (McDermott, 2010). When utilizing the SWH template, students generated and clarified their understanding of scientific concepts for themselves, rather than simply communicating with a teacher for evaluation. They also develop science process skills in the course of the experiments and writing heuristics. Şen and Sezen-Vekli (2016) and Arnold (2011) have showed that science process skills can be developed by using inquiry,

science writing heuristics (discovery learning) or investigative approach of teaching and learning science that gives them opportunities to practice these skills. This idea is also supported by Burner's (1966) theory that instruction should address four major aspects in learning: predisposition of the learner towards learning, the ways in which a body of knowledge can be structured so that it can be most readily grasped by the learner, the most effective sequences in which to present the learning material, and the nature and placing of rewards and punishments. The use of SWH incorporates these instructional skills in the learning process of students. The use of SWH templates by the students result in simplifying, generating new propositions, and increasing the manipulation of information, thus, improving on their science process skills.

SWH helped the students to solve problem by using scientific attitude, demonstrate the experiment, illustrate the results of the experiment, acquire knowledge about new science concepts, think independently, collect and analyze data for information and therefore acquired the science process skills of observing, experimenting, inferring, classifying and communicating. The conventional teaching method (traditional laboratory method) on the other hand do not reinforce science process skills or teach the students how to work together for a common goal, without additional guiding questions.

The conventional laboratory write-up may require the students to make sense of their results, but more from the perspective of whether their result supported their hypothesis. The traditional laboratory write-up is compartmentalized: purpose, hypothesis, experimental design, data, and conclusion; the conclusion answering the question of whether their hypothesis was correct or not. This fails to make the laboratory experience personal for the students. On the other hand, SWH arranges for students to interact

frequently and in smaller, more intimate groups. Having knowledge of the social and cognitive behaviours of the adolescent, the teacher utilizes SWH to assist these delicate students to work with their peers to build positive relationships and attitudes about learning science and acquisition of science process skill. Evidence from Dirks and Cunningham (2006) showed that freshmen who participated in a course in which they were explicitly taught science process skills out-performed students who did not participate in the program in subsequent introductory biology courses

SWH is not just a tool used for writing the laboratory reports but rather an argument-based inquiry because it successfully integrates inquiry activities, collaborative group work, meaning making via argumentation and writing-to-learn strategies. The use of SWH therefore leads to acquisition of science process skills. The findings of this study supports that of Tseng (2014) who reported significant difference in critical thinking skill acquisition for students taught using SWH and traditional instruction in favour of SWH.

Effectiveness of SWH on Achievement and Science Process Skills Acquisition of Male and Female Students in Biology

The results of the study also revealed that the effect of SWH on male and female students' achievement using their pretest and posttest mean scores did not differ significantly. This observed difference is explained from the fact the male students formed stronger clicks and therefore interacted more during the study than the females. The researcher observed during the experiments that both male and female students were actively involved during the experiments. There strong interactions between male and female during the studies.

This finding explained why no significant interaction effect of teaching methods and gender on achievement scores of the students was observed in the study. Thus, the

achievement of students in relation to teaching methods was influenced by gender of the students. The plot of the interaction effect between gender and teaching method was not significant and ordinal. The findings of the study support that of Tseng (2014) who reported that interactions revealed that females had higher gain scores than males at lower grade levels but the reverse was true at higher grade levels.

The results of the study also, revealed that male and female students did not differ significant on effect of SWH on their acquisition of science process skills of observing, experimenting, inferring, classifying and communicating, taught biology using science writing heuristics (SWH) teaching approach. Effects of SWH on male and female science process skill acquisition did not differ significantly. There was also no significant interaction effect of teaching methods and gender on science process skills of observing, experimenting, inferring, classifying and communicating. This shows that the mean scores of students in individual science process skills measured in relation to the two teaching methods is not influenced by gender of the students. There is no significant interaction effect of teaching methods and gender on mean science process skills scores of male and female students.

Conclusion

The study revealed that the effect of SWH approach on achievement of students in biology was significant when compared with those taught using conventional method using their pretest and posttest mean scores and did not differ for male and female students. This showed that the effect of SWH approach on science process skills of observing, experimenting, inferring, identifying and communication was significant when compared with those taught using conventional method using their pretest and posttest mean scores

and did not differ for male and female students. The study also established that SWH positively enhance the students' achievement and science process skills acquisition of observing, experimenting, inferring, classifying and communicating.

Implications of the Study

The implication of the findings of this study is that biology teachers' adoption of SWH would indeed help students to acquire and improve science process skills through the set of activities involved in using the SWH templates. Students' achievement would also be improved whereas biology teachers consider the adoption of SWH approach to teaching biology.

Recommendations

The following recommendations are made in the light of the findings of this study:

1. School administrators should organize seminars and workshop for biology teachers to acquaint them with science writing heuristic instructional approach.
2. Provision should be made by government for students' templates just as there are work/exercise books in different subject areas. The templates should be made ready and designed according the content areas for each term so that students can utilize them for every experiment.
3. Enough time should be allotted to biology practical lesson by education administrators so that teachers can effectively use SWH to teach students important biology concepts that can enable the students transfer their knowledge to real life experiences.

Limitations of the Study

The use of SWH required serious planning considering the academic levels of the students and the teachers' experience in the use of SWH. The secondary school timetable did not quite favour the adoption of the teaching approach and the researcher found it very difficult to execute all the activities as contained in the template.

Suggestions for Further Studies

The following are suggested for further studies:

1. The effect of the use of SWH on students' interest and attitude to biology experiments should be conducted.
2. A study on the effects of SWH on the achievements of students with different cognitive style is suggested.

`REFERENCES

Akinbobola, A.O., & Ado, I.B. (2007). Hands-on and minds-on strategies for teaching of force: Guided discovery approach. In E. Udo, U, Uyoata, N.E.U. Inyang, H. Yero, & G. Bello (Eds), *Hands-on and minds-on strategies in the teaching of force* (pp. 1-12). Uyo: STAN publication.

Akinsanyo, O., Ajayi, K.O., & Salomi, M. (2014). Relative effects of parents' occupation, qualification and academic motivation of wards on students' achievement in senior secondary school mathematics in Ogun State. *Journal of Education and Practice, 5*(22), 99-105.

Ali, A., Toriman, M., & Gasim, M. (2014). Academic achievement in biology with suggested solutions in selected secondary schools in Kano State, Nigeria. *International Journal of Education and Research, 2*(11), 83–85.

Arnold, P.A. (2011). *Investigating the impact of the science writing heuristic on student learning in high school chemistry*. Wisconsin: White water, Wisconsin graduate school press.

Balgopal, M., & Wallace, A. (2013). Writing-to-learn, writing-to-communicate, & scientific literacy. *The American Biology Teacher, 75(3),* 170-175.

Bella, N. (2014). *Stakeholders blame poor exam performance of Nigerian students on poor teaching, in-different parents, technological distractions*. Retrieved from Https://www.bellanaija.com/2014/09/

Bruner, J. (1966). *Constructivism*. Retrieved from http://sydney.edu.au/education_social_work/learning_teaching/ict/theory/constructivism.shtml

Coil, D., Wenderoth, M.P., Cunningham, M., & Dirks, C. (2010). Teaching the process of science: faculty perceptions and an effective methodology. *CBE-Life Sciences Education, 9(1),* 524-535.

Ching-Mei (2014). Effect of science writing heuristics (SWH) approach versus traditional instruction on yearly critical thinking gain scores in grade 5-8 classrooms. (Unpublished thesis), University of Iowa.

Dirks, C., & Cunningham, M. (2006). Enhancing diversity in science: Is teaching science process skills the answer? *CBE Life Science Education, 5(1),* 218-226.

Drobitsky, T. (2015). *Using science writing heuristics to increase conceptual understanding of properties of matter and property changes with 8thgrade students.* (Unpublished masters thesis). Arizona State University, Arizona.

Ende, F. (2012). Not another laboratory report. *Science Scope, 35(5),* 44-50.

Erduran, D. (2014). The effects of science writing heuristics on pre-service teachers' achievement and science process skills in general physics laboratory course. *Pakistan Journal of Statistics, 30(6),* 321-336.

Ezeano, C.A. (2013). Extent of lab-works taught / exposed to senior secondary school 3 chemistry students before external examinations in Enugu State. *Journal of Education and Practice, 4(27),* 23-31.

Federal Republic of Nigeria (FRN), (2004). *National policy on education*. Lagos: NERDC Press.

Femi, O., & Adewale, A.M. (2012). The effects of parental socio-economic status on academic performance of students in selected schools in education L.G.A of Kwara state Nigeria. *International Journal of Academic Research in Business and Social Sciences, 2(7),* 230-239.

Greenbowe, T.J., Poock, J.R., Burke, K.A., & Hand, B.M. (2007). Using the science writing heuristic in the general chemistry laboratory to improve students' academic performance. *Journal of Chemistry Education, 84(8),* 23-33.

Gunel, M. (2006). Investigating the impact of teachers' implementation practices on academic achievement in science during a long-term professional development program on the science writing heuristic. *Science and Mathematics Education Commons, 2(2) 123-125.*

Gunel, M., Hand, B., & Mc Dermott, M. (2009). Writing for different audiences: Effects on high school students' conceptual understanding of biology. *Learning and Instruction, 19(2),* 354-367.

Handelsman, J., Miller, S., & P fund, C. (2007). *Scientific Teaching*, NewYork: Freemanand W.H. Company.

Karamustafaoglu, S. (2011). Improving the science process skills ability of science student teachers using I diagrams. *Eurasian Journal of Physics and Chemistry Education, 3(1),* 26-38.

Karsli, F., & Sahin, C. (2009). Developing worksheet based on science process skills: Factors affecting solubility. *Asia-Pacific for union Science Learning and Teaching, 10(1),* 42-49.

Kingir, S. (2011). *Using the science writing heuristic approach to promote student understanding in chemical changes and mixtures*.(Unpublished masters thesis). Middle East Technical University, Turkey.

Kingir, S., Geban, O., & Gunel, M. (2012). How does the science writing heuristic approach affect students' performances of different academic achievement levels? A case for high school chemistry. *Chemistry Education Research Practical, 13(1),* 428-436.

Leonor, J.P. (2015). Exploration of conceptual understanding and science process skills: a basis for differentiated science inquiry curriculum model. *International Journal of Information and Education Technology, 5(4),* 23-45.

Mason, L., & Boscolo, P. (2000). Writing and conceptual change: What changes? *Instructional Science, 28(1),* 199-226.

Mc-Dermitt, M. (2010). More than writing-using multimodal writing tasks in science classrooms. *The Science Teacher, 3(1),* 32-36.

Mei, G., Kaling, C., Xingi, C., Sing, J., & Khoon, K. (2007). *Promoting science process skills and there levance of science through science alive! Programme Proceedings of the Redesigning Pedagogy.* Paper presented at the Culture, Knowledge and Understanding Conference, Singapore.

Metz, S. (2006). Science literacy: Then and now. *The Science Teacher. 73(2),* 8-9.

Mutisya, S.M., Too, J.K., & Rotich, S. (2014). Performance in Science Process Skills: The Influence of Subject Specialization. *Asian Journal of Social Sciences & Humanitie, 3(1),* 23-29.

Nwafor, C.E., Obodo, A.C., & Okafor, G.(2015). Effect of Self-Regulated Learning Approach on Junior Secondary School Students' Achievement in Basic Science. *Journal of Education and Practice, 6(5),* 22-28.

Nworgu, B. G. (2015). *Educational research: Basic issues and methodology*. Ibadan: Wisdom Publisher Limited.

Ozden, M., & Gultekin, M. (2008). The effects of brain-based learning on academic achievement and retention of knowledge in science course. *Electronic Journal of Science Education, 12(1),* 23-29.

Ozmon, H.A., & Carver, S.M. (2008). *Philosophical foundations of education* (8^{th}.ed.). Upper Saddle River, NY: Pearson/Merrill Prentice Hall.

Saribas, D., Bayram, H. (2009). Is it possible to improve science process skills and attitudes towards chemistry through the development of metacognitive skills embedded within a motivated chemistry lab: A self-regulated learning approach. *Procedia-Social and Behavioral Sciences, 1(1),* 61-72.

Şen, C., & Sezen-Vekli, G. (2016). The impact of inquiry based instruction on science process skills and self-efficacy perceptions of pre-service science teachers at a university level biology laboratory. *Universal Journal of Educational Research, 4(3),* 603-612.

Yeoman, K.H., & Zamorski, B. (2008). Investigating the impact of skill development of an undergraduate scientific research skills course. *Biological science Education, 3(22),* 29-33.

APPENDICES

APPENDIX A

List of Secondary Schools in Oshimili North Local Government Area of Delta State

3. Akwukwu-Igbo Grammar School Akwukwu-Igbo
4. Atuma-Iga Government Secondary School Atuma-Iga
5. Ebu Secondary School Ebu
6. Illah Basic Secondary School Illah (Single sex)
7. Illah Mixed Grammar School Illah
8. Ibusa Girls Grammar School Ibusa (Single sex)
9. Okpanam High School Okpanam
10. Omu Boys Secondary School Ibusa
11. St Thomas's Grammar School Ibusa
12. Ugbolu Secondary School Ugbolu
13. Ukala-Okpuno Grammar School Ukala-Okpuno

APPENDIX B

HEURISTIC BIOLOGY ACHIEVEMENT TEST (HBAT)

NAME OF SCHOOL: ……

GENDER: MALE ( ) FEMALE ( )

INSTRUCTION:

1. Erase completely any rejected answer.

2. You are not timed, therefore submit the test booklet and your answer sheet immediately you complete or finish working.

3. Ask questions if you do not understand any of the instruction.

4. Be careful with the test booklet. Do not write anything inside it. Do not tear any part of the question booklet.

SECTION B

Answer all questions, each question carries equal marks

1 Double fertilization is said to occur in flowering plants because.....

(a) two embryos are formed (b) one egg is fertilized twice (c) two sperm fertilize each egg (d) one embryo and an endosperm nucleus is formed

2. The ripening of the Stamen before the pistil in flowering plants is referred to as (a)protogyny (b) unisexuality (c) protangry (d) self-incompatibility.

3. Which structure in the maize grain stores food. (a)endosperm (b)embryo (c) seed coat (d) radicle

4. Which of the following is not an example of entomophilous flower? (a)Hibiscus (b) flamboyant (c) guinea grass (d) allamanda

5. After fertilization in the flowering plant, the zygote develops into the (a)Plumule (b) radicle (c) cotyledon (d) embryo

6. In flowering plants fertilization would occur when

(a)The pollen grows downwards penetrating the style

(b) a pollen grain is transferred to the stigma

(c) one of the nuclei inside the pollen tube fuses with the ovum

(d) the nucleus of the pollen tube divides.

7. Plant having both male and female flowers on the same plant is said to be..... (a) Regular (b) monoecious (c) irregular (d) dioecious

8. The embryo of developed seed passes through a stage of rest called..... (a) dormancy (b) hibernation(c) regeneration (d) sleep

9. The type of germination in which the cotyledons or seed are carried above the soil surface is referred to..... (a) hypogeal (b) dicot (c) epigeal (d) monocot

10. Xerophytes are better adapted in arid land due to..... (a) reduced leaves (b) big trunk (c) long branches (d) broad leaves

11. The process of development of embryo of the seed into a seedling is called (a) germination (b) growth (c) fertilization (d) adaptation

12. Xerophytes carryout photosynthesis through the aid of chlorophyll in the..... (a) branches (b) root (c) leaves (d) stem

13. Cowpea exhibit……. type of germination (a) late germination (b) epigeal germination (c) hypogeal germination (d) early germination

14. The adaptive feature in xerophytes that helps to reduce the rate of transpiration is (a) growth in arid land (b) possession of waxy cuticle (c) large stems (d) regeneration of leaves

15. Which is the condition necessary for germination of seed (a) air and oxygen (b) coated shell (c) large surface area (d) hydrogen and air

16. Actinomorphic flower are termed as (a) regular flower (b) bilateral symmetrical flower (c) irregular flower (d) insect pollinated flower

17. At the early stage of the development of a tadpole when it has no mouth, the tadpole feeds on (a) egg yolk (b) oxygen (c) water weed (d) insects

18. The toad is a .....living in an aquatic habitat (a) an avies (b) a mammal (c) an amphibian (d) a reptile.

19. All the following are adaptive features of a xerophyte except .... (a) reduced leaves (b) succulent stem (c) possession of spines as leaves (d) possession of broad leaves.

20. .....is an example of a xerophyte (a) hibiscus flower (b) cactus plant (c) tridax plant (d) pawpaw

21. The internal gill stage of toad develops within (a) 4-5days (b) 6-10days (c) 15-20days (d) 7-9days

22. The eggs of toad are laid in the above (a) jelly-like covering (b) coated shell (c) thick epidermis (d) hard shell

23. The hole that permits water and air into the embryo of the seed is called .....

(a) micropyle (b) hilum (c) testa (d) plumule

24. One of the following is characteristic of a xerophyte (a) has large leaves (b) folding of leaves (c) loss water to the environment (d) has woody stems

25. Which of the following is not an example of entomophilous flower? (a)Hibiscus (b) flamboyant (c) guinea grass (d) allamanda

MARKING SCHEME FOR HBAT

Each Question carries one mark (4marks)

1. A	6. B	11. A	16. A	21. B
2. C	7. B	12. D	17. A	22. A
3. A	8. A	13. B	18. C	23. A
4. A	9. C	14. B	19. D	24. B
5. D	10. A	15. A	20. B	25. B

(TOTAL = 25 ×4 = 100 MARKS)

APPENDIX C

TABLE OF SPECIFICATION FOR HBAT

Topics	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation	Total
Stages of Development In a toad	2	1	1		1		5
Germination of seeds	2	2	1	1			6
Reproduction in flowering plants	3	3	1	1	1		9
Adaptation in xerophytes	1	2	1		1		5
Total	8	8	4	2	3	4	25

APPENDIX D

SCIENCE PROCESS SKILL ACHIEVEMENT TEST (SPSAT)

Answer All Questions

1a. Observing specimen, A, copy and complete the table below

Specimen	Floral parts	Number of parts	Colour	Free, fused or United	Essential or non-essential
A	Sepals/Calyx				
	Petals/Corrola				
	Stamens				
	Stigma				

1b. Cut specimen A longitudinally into two halves. Observe the halved specimen A and use it to answer Questions b (i – ii)

i. What is the symmetry of specimen A

ii. Classify Specimen A in relation to its reproductive structures

1c. Detach the Sepals and Petals of the longitudinal section of specimen A and make a labelled drawing of 10cm -12cm to illustrate the features of the remaining parts of specimen A.

2ai. Identify Specimen B with reasons

2aii. Examine the ventral part of specimen B and list four observable features.

2bi Suggest the diet of specimen B, giving reasons.

2bii. Identify one (1) feature on the ventral part of specimen B which suggest its habitat.

2c. Make a labelled drawing of 8cm – 10 cm long of the lateral view of Specimen B

3a With the aid of specimen C, List 5 adaptive features of the specimen to its environment

3b. Identify specimen C and state its habitat

4a. Draw and label an illustration of hypogeal and epigeal germination of Seed, showing the cotyledon above the ground and below the ground

4b. In a tabular form, list the conditions necessary for germination of

seed and the reasons

MARKING SCHEME FOR SPSAT (40 MARK)

1a

Specimen	**Floral Parts**	**Number Of parts**	**Colour**	**Free or Fused Or United**	**Essential or Non-essential**
K	Sepals/Calyx	5	Green	United	Non-essential
	Petals/corolla	5	Red	Free	Non- essential
	Stamens		Orange (red)	United	Essential
	Stigma	5	Red	Free	Essential

(**20 Marks)**

Ib)i. Bilateral **(2 Mark)**

ii. Specimen A is an Angiosperm-possesses flower for external reproduction. **(2Mark)**

1c

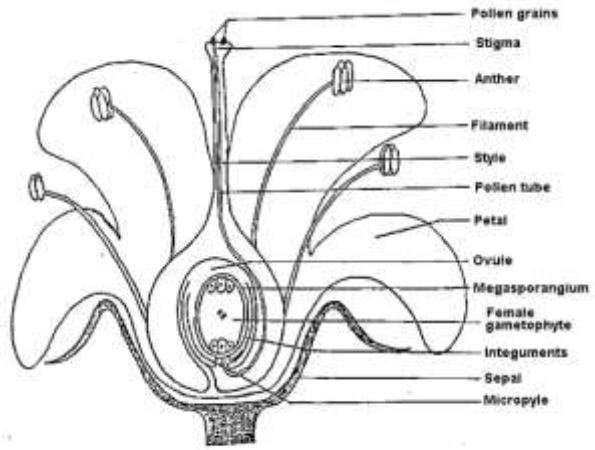


Diagram showing longitudinal section of hibiscus flower (**16 marks)**

(2 a) i. Specimen B is an amphibian, a tadpole with internal gill and limb (**4 Mark)**

(2a) ii. Mouth, operculum, spout and hind limb (**12 Mark)**

(2b) i. The diet of specimen B is water weeds

REASONS:

Possession of horny mouth parts to crush its food
Possession of lungs and coiled intestine to provide surface area for digestion
(4 Mark)

ii. The hind limb on the ventral part of specimen B is not used by the organism at this stage, because it moves by means of the tail fin. **(4 Mark)**

2c.

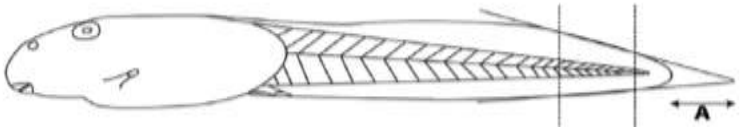


Figure 2: Diagram Showing Lateral View of Tadpole (12 Marks)

3a. 1. Possession of little or needle like leaves to avoid loss of water through transpiration

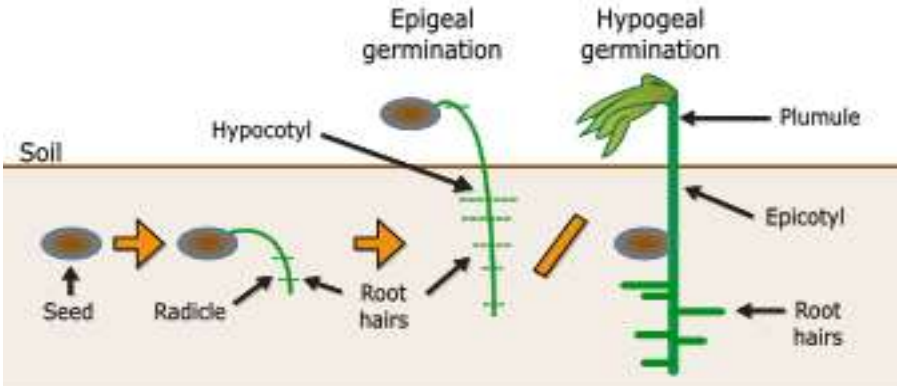
2. Storage of water in its stem
3. Stem carryout photosynthesis
4. Leaves reduced to needle and spine to avoid loss of water
5. Deep and extensive root to absorb water and other soil nutrients

. (5marks)

3b. Specimen C……. is cactus. (2mark)

Habitat ……... arid land. (2mark)

4a. Diagram of hypogeal and epigeal germination



(10 marks)

4b. Conditions necessary for germination of seeds

Conditions	Reason
Sufficient water/moist	Enables the seed to swell, the testa burst and the embryo gets water and insoluble stored food become soluble for the seed
Warmth or suitable temperature	Dry seed receives warmth for activities of enzyme
Oxygen	It needed by germinating seed for respiration
Viable seed	Only seed whose embryo is not damaged can germinate
Good soil	Good soil is required for germination

(5marks)

Question No.	Scores on Skills				
	Observing	Experimenting	Inferring	Classifying	Communicating
1a	16			4	
1bi		2			
1bii				2	
1c		5			11
2ai	2		2		
2aii	4	4			4
2bi			4		
2bii			4		
2c		5			7
3a			5		
3b	2		2		
4a				2	8
4b			5		
Total	24	16	22	8	30

Total (100Marks)

The distribution of scores among the five skills measured for each question is as follows:

1a. Students who are able to write down the number of floral parts correctly, listed the number of each floral part and the colour of each floral part and show whether they are fused or united would have observed very well and scored **16marks** and those who are able to classify the floral parts as essential or non-essential scores **4 marks** on classification.

1bi A good cut of specimen A longitudinal into two halves and good identification of the symmetry expresses experimental skill which earns the student **2marks.**

1bii Ability to classify the reproductive structure of A earns the students **2 marks** on classifying skills

1c Correct detachment of the sepal and petal shows good experimenting skills and earns the student **5marks** while ability to draw the diagram of the specimen earns the students **11 marks** on communicating skills.

2ai **2marks** for proper identification which expresses good observation and **2marks** for giving reason which shows the students' ability to infer.

2aii good examination shows good experimental skills **4marks,** good observation **4marks,** and ability to name what they observed, good communication **4marks**

2bi, bii Correct suggestion with reason shows good inferring skill **4 marks** for each question

2c Drawing the diagram and labelling correctly shows good experimental and communication skills **5marks** experimental, **7 marks** communication

3a Suggesting the adaptive features shows good inference **5marks**

3b Identify shows observation **2marks,** state the habitat based on what was identify shows good inference **2marks**

4a good drawing of hypogeal and epigeal germination shows good classificatory and communication skills, **2marks, 8 marks** respectively

4b stating the condition shows good inference **5marks.**
These score were converted to percentages.

APPENDIX E

Table of specification for SPSAT

Topics	Observing	Inferring	Experimenting	classifying	Communicating	Total
Stages of Development In a toad	1	4			1	6
Germination of seeds		1			1	2
Reproduction in flowering plants	2		1	1	1	5
Adaptation in xerophytes			1			1
Total	3	5	2	1	3	14

APPENDIX F

Lesson plans and Templates on SWH

SWH Teacher Template for Week One

Subject: Biology

Class: Senior secondary year II

Time: 80mins

Topic: Stages of development in Toad

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

1. List the stages in the development of a toad
2. Identify and describe with the aid of a diagram, the various changes that occur during the development of a toad
3. List the general adaptations of a toad to its natural habitat
4. Write report using science writing heuristics on what was learnt

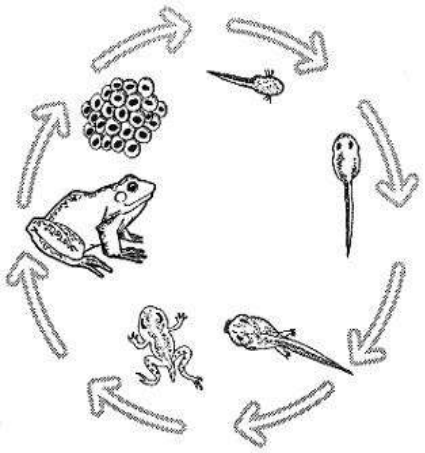
Instructional Materials: SWH students' template, Live specimen of a tadpole and a toad, student were asked to visit stagnant water around the school environment to see the various stages of how a tadpole develops.

Entry Behaviour: the students have observed stagnant water before the class to see how a toad develops in its natural habitat

Set Induction: The teacher sets induces the student by asking them to state the different stages of development of a toad observed in the stagnant water.

Content development	**Teachers' Activity**	**Students' Activity**	**Teaching skills**
Step I Introduction	The teacher takes the students outside the classroom to pools of stagnant water to observe development of toads in their natural habitat.	The students observe the tadpoles and toads in the pool of stagnant water and record their observations.	Observation and experiment.
Step ll	The teacher distributes the science writing heuristics (SWH) template to each student to solve the problems written on it, using the observation and report of their findings from their experiment outside the class.	Using the reports from their observation and findings from their visit to the pools of stagnant water outside the classroom, the students answer the questions in their template.	Communication
Step III	The teacher asks students to stop working on their template, and ask them to exchange their template with their classmate. The teacher also asks them to compare their work to see how their ideas differ from that of their classmates	The students exchange their template and compare their work.	Communication
Step IV	Stages of development in toads. The teacher writes the topic on the board and instructs the students to retrieve their templates. Hangs a chart showing	The students retrieve their templates from their classmates and observe the specimens and chart on the board.	Observation

	the stages of development of a toad on the board and displays specimen of eggs, tadpole and toad on the student's work station for the students to observe. he teacher then asks the students the following questions to know their area of weakness in the topic, 1. What is a habitat 2. What is the habitat of a toad? 3. What group of organism does the toad belong to? 4. What type of reproduction does the toad undergo? 5.What are the stages of development of a toad, as observed in its natural habitat? From the response of the students the teacher identifies students weakness, makes the necessary corrections and explains that the toad undergoes sexual reproduction which occurs between the sperm of the male toad and the egg or ovum of the female toad. There are six stages in the development of a toad 1. The egg stage 2. The external gill stage 3. Internal gill stage 4. The limb stage 5. The young toad stage	The students answer the questions.	Communication

	6. The adult toad The teacher gives detail explanations on these stages with the aid of a chart showing stages of development of a toad.  **Diagram of stages of development in a toad.**		
Step V Adaptation of a toad to its habitat	The teacher explains adaptation to the students', as the possession of special features and structures which improves the chances of an organism's survival in its environment. The teacher asks the students to state the different features in the toad that enables it to adapt to its habitat. The teacher explains the features that enables the toad adapts to its environment as follows, 1. Possession of special olfactory	The students listen to the teacher The students answer the question. The Students pay attention to the teacher and identifies the adaptive features	Inference Classification

	organ in the head for smelling. 2. Ability to draw its eyes into a bulge at the roof of its mouth to swallow its prey and prevent it from escaping. 3.possession of a long tongue attached to the front of its mouth used for capturing its prey. 4. Webbed feet for swimming 5. Streamlined body for swimming etc.	from the specimen given to them.	
Step IV Evaluation	The teacher evaluates the students by asking them the following questions; 1. List the stages of development in toads? 2. With the aid of a diagram identify and describe the various changes that occur during the development of a toad? 3. List the general adaptation of a toad to its	The students answer the questions correctly.	Feedback.
Step V Summary	At the end of the exercise, a board summary of the lesson is done and the students are asked to answer the question on the students' reflection question template on the topic taught as take home assignment. The students are asked to plant maize and bean seeds in a beaker in preparation for the next class. The students are also asked to record their day to day observation on the germination of the seeds.	The students' copy the board summary in their notebook and also go home with the student reflective question as assignment.	closure

SWH Students Template for Laboratory Activities

<table>
<tr><td>Date:

Topic: Stages of development in a toad</td><td>Name of student:</td></tr>
<tr><td>Experiment:</td><td rowspan="3">Records of observation</td></tr>
<tr><td>Duration of practical activity:</td></tr>
<tr><td>Name the location where toads are found?

Give three (3) reasons for choosing the location.</td></tr>
<tr><td>What are the evidence to show that breeding is taking place in the water and what kind of organisms live in the water?</td><td>What are the stages of development of the organisms as seen in their habitat?</td></tr>
<tr><td>What is the main aim of carrying out the experiment?</td><td></td></tr>
<tr><td>List some of the external features of the tadpole and that of the toad as seen in its natural state and habitat</td><td></td></tr>
<tr><td>What are the specimen and apparatus provided for the experiment?</td><td>How many of these apparatus was gotten from the laboratory or improvised?</td></tr>
</table>

Using the specimen and apparatus provided, list some of the external features you can see on the specimen	Procedure: What are the adaptive features of the toad to it environment?

Observation:	
Did you observe any difference from what you were taught in class?	What are the reasons for the difference?
What claims can you make now that you have completed the experiment?	What skill did you use to carry out the experiment?
What is your conclusion on the experiment?	Draw and label the six stages of the

Did you draw the diagrams to scale? What was the size of your diagram and magnification of lens used during the observation?	development of a toad
compare your report of the experiment with that of your classmate What did you observe in your classmate's work? How do my results compare or differ from theirs?	
Read the chart on the board showing the stages of development in a toad and compare it with your work. Based on the teacher's explanation, how do my ideas, evidence and observations compare to what I observed.	

SWH Template used for Students' Reflection Questions (Assignment)

BIOLOGY LABORATORY Reflections: What did I learn from the experiment? ……
What are the possible things I can repeat so that I can verify my observations, to notice my mistakes and improve in areas where I have difficulties? What would I have done differently?
How have my ideas changed about carrying out the experiment on my own without assistance of my class teacher?
Comment on your work compare to that of your teacher taught in the laboratory?
Based on your understanding, explain in details the benefits of using real life objects as specimen? ……

……..

List some of the knowledge/science process skills acquired while carrying out the experiments on your own?

……
……

Teacher Template for Week Two

Subject: Biology

Class: Senior Secondary School year II

Duration: 80 Mins.

Topic: Germination of seeds

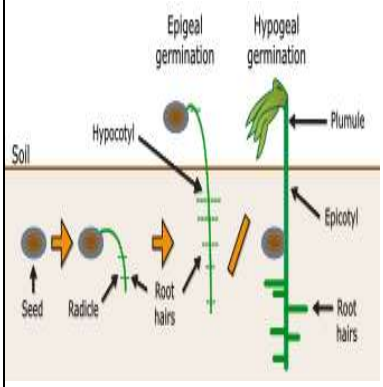
Specific objective: At the end of the lesson, students should be able to;

1. Define germination
2. Describe with examples how seeds germinate
3. Enumerate 5 factors that are of importance for the germination of seeds.
4. State the period of germination of bean and maize seeds
5. List 3 conditions necessary for the germination of seeds.
6. Draw and label an illustration showing the germination of seeds.
7. Mention the 3 types of germination of seeds.
8. Differentiate between the 2 types of germination of seeds.

Entry Behaviour: students planted and monitored the day to day growth of bean and maize seeds and recorded their observations.

Set induction: The teacher asks the students to display their beaker containing the seedling of the seed they planted on their work station. The teacher then asks the students questions about their observations of the seeds they were asked to plant.

Content Development	Teachers' Activity	Students' Activity	Teaching Skill
Step l Introduction	The teacher introduces the topic by asking the students the following questions: 1. State the procedure you took to plant the seeds? 2. What were the apparatus needed to carry out the experiment on germination of seeds? 3. How long did it take for the seeds to germinate? 4. What are the conditions necessary for seeds to grow? 5. What were your observations from the first day the seeds were planted?	The students answer the questions on their science writing heuristics template.	Experiment, observation and communication.
Step II	The teacher asks students to stop working on their template, and ask them to exchange their template with their classmate. The teacher also asks them to compare their work to see how their ideas differ from that of their classmates	The students exchange their template and compare their work.	Communication

Step III Germination of Seeds Types of germination	The teacher writes the topic on the board, then defines germination as: the process which involves the gradual development of the embryo of the seed into a seedling of a young plant, when the conditions are unfavourable. Seeds undergo several changes to develop into seedlings. There are two types of germination, these are: i. Epigeal germination ii. Hypogeal germination Epigeal germination is the type of germination in which the cotyledons or seed leaves are carried above the soil surface. E.g. dicotyledonous plant. (bean, Cowpea, groundnut, melon, Mango, etc.). Hypogeal germination is the type of germination in which the cotyledons, seed leaves, or endosperm remains below the soil. E.g maize seed.  **Diagram of types of germination**	The students' listen to the teacher's explanation. The students examine the seedling in front of them to confirm the type of germination that took place in the seeds they planted.	Communication Classification

Step IV Conditions necessary for germination of seed	The teacher enumerates the conditions necessary for germination of seeds as follow: 1. Water or moisture: needed to activate the cell, soften the testa or seed coat for the radicle and plumule to come out of the seed. 2. Air or oxygen: The seed as a living organ needs oxygen to carry out respiration. 3. Warmth/suitable temperature: is required for the seed to germinate. 4 Enzymes: Organic catalyst which help to speed up the rate of chemical reaction within the cells in the seed. 5. Energy or food: There must be food within the seed from which it feeds. Food is stored in the cotyledons of dicotyledonous seed while food is stored in the endosperm of monocotyledonous seed. 6. Viable seeds: For seed to germinate and grow the seed must be alive, i.e not damaged by insects, birds or man	The students listen to the teacher and compare the teacher's explanation with what they wrote down in their SWH template	Inference
Step V Assignment	The teacher instructs the students to carry out the afore given experiment putting all the conditions taught during the lesson in place, using the procedure written on their SWH template as a guide. Apparatus: Four conical flasks, cotton wool, string, stopper, bean seeds, solution of pyrogallic acid and caustic soda, Test tube and water.	Students share themselves into small groups of five and carryout the experiment.	Experiment

	Procedure: Place the bean seeds and cotton wool in each of the conical flask A, B, C and D. and close with a stopper. Conical flask A, is left in a warm place Conical flask B, put a little water to moisten the cotton wool, suspend a test tube containing pyrogallic acid and caustic soda in the conical flask with the aid of a string. NOTE: Pyrogallic acid absorbs oxygen while caustic soda, absorbs carbon dioxide from the flask. Conical flask C is kept in a warm place and place, keep flask D in a refrigerator and leave the flask for a few days and come back before the next class to record their observation individually. The conditions in each of the flask are as follows: Flask A: warmth, oxygen, no water Flask B: warmth, water, no oxygen Flask C: warmth, oxygen, water Flask D: oxygen, water, no warmth Observation: only the seeds in flask C germinated because it has the conditions necessary for		

	the germination of seeds which are not contained in flask A, B and D. Conclusion: The experiment shows that, warmth, oxygen and water is necessary for seed to germinate.		
Step VI Evaluation	The teacher evaluates the students asking the students the following questions: 1. Define germination 2. Describe with examples how seeds germinate 3. Enumerate 5 factors that are of importance for the germination of seeds. 4. State the period of germination of bean and maize seeds 5. List 3 conditions necessary for the germination of seeds. 6. Draw and label an illustration showing the germination of seeds. 7. Mention the 3 types of germination of seeds. 8. Differentiate between the 2 types of germination of seeds	Students answer the questions correctly.	Feedback

Step VII Summary	At the end of the lesson, a board summary of the topic is given to the students SWH reflection question template is distributed to the student as take home assignment. The teacher reminds the student to come back after 2-3 days to record the observation of the experiment carried out on conditions necessary for germination of seeds.	Students' copy the board summary on their notebooks, collects their reflective question template and ensure that their experiment under observation is kept in a safe place.	Closure

SWH Student Template

Name of Student:

Topic: Germination of seeds

Date:

Duration of the experiment:

<table>
<tr><td>What is the aim of the experiment?</td><td></td></tr>
<tr><td>List the apparatus provided for the experiment</td><td></td></tr>
<tr><td>How many of the apparatus provided for the experiment where provided from the laboratory or improvised?</td><td></td></tr>
<tr><td>Procedure for the experiment: Take five glass beakers (100ml) and label them A, B, C, D and E.

Fill beakers’ A, B, C and D with loamy soil up to three quarter level and leave beaker E empty without soil. Plant healthy seeds (bean, okra, or maize) in the first three beakers (A, B and C).

Plant a defective (spoilt) seed on beaker D, place viable (healthy) seed on beaker E that is without soil.</td><td>Procedure after planting the Seed: Keep The Beakers Labelled A and D in a place where sunlight Is available outside.

Keep the beakers labelled B and C within the shelf or work station where there is no sunlight.

Keep the beaker labelled E outside where sunlight is available.</td></tr>
<tr><td colspan="2">Maintenance of the seeds planted

Endeavour to look out for the seed growth with proper care and observations. Water seeds planted on beaker A, C and D for the next five to six days regularly during morning time and no watering should be done on beaker B.

Ensure that you observe the changes in seeds planted in all the beakers, if possible consult biology practical textbooks on information given about seed germination to compare the changes observed on the seed planted to arrive at the final conclusion of the experiment.</td></tr>
</table>

Record of changes that occurred on the seeds planted

Beaker	Changes on the seed observed from day 3 – day 5	Reasons for changes
A		
B		
C		
D		
E		
	Result of the experiment:	
	Did you follow the procedure and instructions on your template to carry out the experiments?	
	What are the precautions taken while carrying out the experiments?	
	Comparing the results of your experiment with that of your classmate, what were the differences you observed that did not reflect in your report?	
	Draw an illustration of your experiment and label it.	

SWH Student Template for Group Work

Topic: _____

Experiment: _____

Name of Student: _____

Time: _____

Aim of the experiment: Conditions necessary for germination of seeds _____

_____

Apparatus: Four conical flasks, cotton wool, string, stopper, bean seeds, solution of pyrogallic acid and caustic soda, test tube and water.

Procedure: Place few bean seeds and cotton wool in each of the conical flask labelled A, B, C and D and close with the stopper.

Conical flask A, is left in a warm place.

Conical flask B, put a little water to moisten the cotton wool, suspend a test tube containing pyrogallic acid and caustic soda in the conical flask with the aid of a string.

Conical flask C and D, pour a little water into each flask, place the flask C in a warm place and place conical flask D in the refrigerator. Come back in 2-3 days to record your observation.

NOTE: Pyrogallic acid absorbs oxygen, caustic soda absorbs carbon dioxide

Observations: What are the conditions in each of the conical flask? ……..

……
……
……

……
……

……
……

What are your observations of the seeds planted in each of the conical flask?	Conclusion:

SWH template for student reflection questions

Reflections:

What did I learn?

……

……
……..?

What are the possible things you can repeat to ensure proper germination and to improve your knowledge in area where you have difficulties?	
How have your ideas changed after carrying out the experiment with your group?	
Did everyone participate equally during the experiment?	
Make comments about your group?	
Based on your experience during the	List some of the knowledge and experiences

experiment, explain in detail the benefits of using real life objects as specimen?	acquired while carrying out the experiment on your own and with your group?
General comments about your group work?	

TEACHER TEMPLATE FOR WEEK THREE

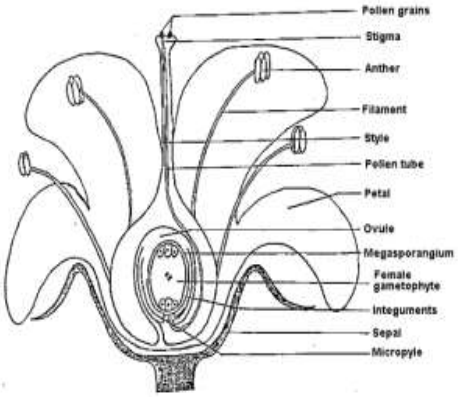
Subject: Biology
Class: Senior Secondary School year II
Duration: 80mins.
Topic: The flower as an organ of reproduction in flowering plant

Specific Objectives: At the end of the lesson student should be able to;
1. Define a flower.
2. Give a brief explanation of placentation in flowers.
3. Define reproduction in flowering plant.
4. Draw and label a transverse section of a named flower (Hibiscus Flower).
5. Differentiate between the male and female part of a flower.
6. Write Short note on arrangement of floral part of a named flower.
7. List the functions of the male and female part of a named flower.

Instructional Materials: Disserting kits, flower from different plants, e.g., hibiscus Flower, pride of Barbados, ixora flower and chart showing a transverse section of a hibiscus flower.

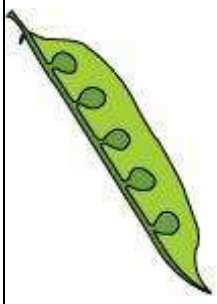
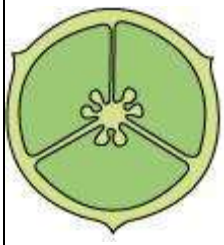
Set Induction: The teacher sets induces the students by asking them to observe the parts of the flowers placed in front of them and write down their observations.

Development	**Teachers activity**	**Students activity**	**Teaching Skill**
Step (I) Introduction	The teacher distributes the students SWH template to be used for the new topic to the students and ask them to carryout the experiment written in the template, comparing their observation with the chart showing the transverse section of a hibiscus flower hung on the board. Based on the students' observations , the teacher introduces the new topic.	The students answer the questions following the instructions on the templates, the students carryout the experiment and use their observations to answer the questions written on the SWH template	Observation , experiment and communication
Step (II)	The teacher explains that the flower is the reproductive organ of flowering plants. It	Students listen to the teacher, reflect	Communication

Reproduction in flowering plant	contains the male and female sex organ which enables the flower to undergo sexual reproduction. Fertilization inside the flower often leads to the production of seeds.	on their experiments to correct some of their mistakes.	
Step (III) Structure of a flower	The teacher explains the structure of the flower with the aid of the chart hanged on the board and the Specimen on the student work station. The Flower is a cluster of modified leaves which is borne on a short stem pedicel or Stalk The flower is made up of four floral parts namely; (i) Calyx (ii) Corolla (iii) Androecium (iv) Gynoecium, these floral part are arranged in concentric rings i.e. one above the other on the receptacle or thalamus I  **Diagram of hibiscus flower**	The Students Listen to the Teacher and Compare the teacher's explanation with the observation written down in their SWH template.	Observation and classification
Step (IV) Functions of the floral part of the flower	1. Calyx (Sepals): This consist of sepals which are usually small and green. it protects the flower which is in the bud. The sepals are either separated (polysepalous) or joined to for a cup (gamosepalous). There may also be an epicalyx such as in hibiscus flower. 2 Corolla (petals): The petals are collectively known as the second whorl or floral part of	Student listen to the teacher and observe the specimen and identify all the part of the flowers on their own and correct their mistakes where	Experiment

	the fowers. Flowers are either polypetalous or gamopetalous. Petals are brightly coloured and scented which attract pollinators, e.g., animal, insect, etc. Both petals and sepals may sometimes look alike, they are referred to as perianth. 3.Androecuim: This is the male reproductive organ of a flower. The whorl inside the petals is a group of Stamens collectively known as the androecium. Most stamens have filament and anther.	necessary.	
	Sometimes the filament is attached to the petal (epipetalous). 4.GynoeciumThis is the female reproductive organ of a flower. It is the inner most part of the floral part of the flower. It may consist of one, few or many carpels (pistil). When it is one pistil, it is monocarpous.Example flamboyant.when it is more than one is polycarpus. when the carpel is free from one another the pistil is said to be apocarpous.		
Step V Types of ovary in a flower	An Ovary can be described as superior, inferior and half inferior in a flower.	The students observe the specimen and identify the type of ovary in the specimen they worked with.	experiment and classification.
	Superior Ovary: The Ovary is placed above the floral part (e.g. Hibiscus), Its flower is described as hypogynous flower. Half inferior: Ovary lies inside a cup shaped receptacle and other floral part appear to be attached slightly above (perigynous flower). inferior ovary: The ovary is placed below other floral part of the flower		

	(Epigynous flower).		
Step vi Description of flower	Inflorescence: Group of flowers attached to a common Stalk e.g. pride of Barbados. Solitary flower: Attached singly to a leaf axis or the tip of a branch, e.g. pawpaw and hibiscus flower. Perfect Flower: Has both carpel and stamen in it, e.g. pride of Barbados. complete flower: has all four floral part of a flower e.g., hibiscus. Incomplete flower: Lacks One or more of the flower part e.g., maize	Students listen attentively and identify the type of flower given to them as specimen and records their observation.	classification and inference..
	Regular flower: All members of the whorl are evenly arranged in their numbers (actinomorphic flower) e.g., hibiscus. Irregular flower: all numbers of the whorl are not evenly arranged some parts are missing (zygomorphic flower). Auxillary flower: Are borne in the axis of leaves. Terminal flower: Are borne at the end of stems or leaves. Monoecious flower: Male and female parts are found on same plant, e.g. maize. Dioeious flower: Male and female part are found on different plant, e.g. Pawpaw.		
Step Vii Placentation in flowering plant	Placentation is the arrangement of ovules within the ovary. kinds of placentation: Marginal placentation: Ovules are attached to the placenta along one margin, e.g. beans, Pride of barbados (a syncarpous ovary, e.g. Pawpaw). Free placentation: ovules are borne on a knob which projects from the base of the ovary e.g. cana lily. Axile placentation: Ovules are attached to the middle of the syncarpous ovary, e.g. tomato.	The Students observe the ovules of the specimen they are working with and record their observation.	Observation, classification inference.
	Basal placentation: Ovules are attached to		

	the base of a syncarpous ovary, e.g. sun flower. **Diagram of kinds of Placentation**  Marginal placentation  Parietal placentation  Axile placentation  Free central placentation		

	 Basal placentation		
Step viii Evaluation	The teacher asks the student following questions: 1. Define a flower? 2. Give a brief explanation of placentation in flowering? 3. Define reproduction in flowering plant? 4. Draw and label a transverse section of a named flower (Hibiscus Flower)? 5. Differentiate between the male and female part of a flower? 6. Write Short note on arrangement of floral part of a named flower? 7. List the functions of the male and female parts of a flowerr	Students answer the questions correctly.	feedback
Step ix Summary	The teacher ends the lesson by giving the students board summary of the topic. Distributes SWH students' reflective questions to the students as take home assignment.	Students copy the board summary and also collect their reflective question templates.	Closure

SWH students' template

Name of student: .....

Topic: The flower as organ of reproduction in flowering plants.

Date:

Duration of experiment:

What is the aim of the experiment?	Procedure for the experiment:
What type of flower is the specimen you are working with?	
What are the apparatus provided for the experiment? .....'	How many of these apparatus where improvised? .....
Dissecting the flower, list the various parts of the flower and their functions?	

What kind of ovary and placentation does the flower have? ..... What type of reproduction does the flower undergo ?	Draw and label longitudinal section of the specimen?
What type of pistil does the flower have?	Observations :
Conclusion:	

Template for student reflection questions

Reflections:

What did I learn?

……
……..?

What are the possible things I can repeat to verify my observations, to improve my	

knowledge in the areas I have difficulties?	
How have your ideas changed after carrying out the experiment?	
Did everyone participate equally during the experiment?	
Make comments about your work?	
Based on your experience during the experiment, explain in detail the benefits of using real life objects as specimen?	List some of the knowledge and experiences acquired while carrying out the experiment on your own?
General comments about your experience working alone?	

TEACHER TEMPLATE FOR THE WEEK FOUR

Subject: Biology.

Topic: Adaptation in Xerophytes.

Class: Senior secondary school year ll.

Date:

Duration: 80mins.

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

1. Define xerophytes.

2. Give examples of xerophytes.

3. State the habitat of xerophytes.

4. State at least 4 features that adapt Xerophyte to their habitat.

Instructional Materials:

1. Live specimen of cactus plant of prickly pear (opontia).

2. Aloe Vera.

3. Christmas.

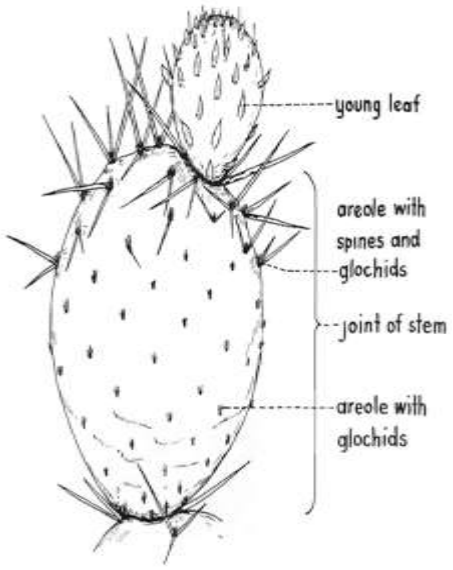
4. Disserting kit.

5. Hand lens.

Entry Behaviour: The students have learnt about adaptation in toads

Set Induction: The teacher set induces the students by asking them to observe the specimen on their work station, dissect the specimen and record their observations

Content Development	**Teachers' Activity**	**Students' Activity**	**Teaching skill**
Step I Introduction	The teacher distributes the students SWH template to be used for the new topic to the students and ask them to carry out the experiment written in the template, comparing their observation with the chart	students observe and dissect the on their work station and use their findings to answer	Experiment and inferring

	showing the transverse section of a matured and young cactus plant hung on the board. Based on the students' observations , the teacher introduces the new topic	the questions on their SWH template.	
Step II Meaning of Xerophytes and examples	The teacher explains that xerophytes are plants which are adapted to survive drought/prolonged dry condition in their habitats. Examples of Xerophytes are shown to the students, using the specimen placed on their work station (Prickly Pear, Barrel cacti, Aloe Vera)  A mature and a young joint of a prickly pear cactus	Students listen to the teacher and compare the report of their findings with the teacher's explanation.	Observation
Step III Structural and functional adaptations	Structural adaptation is explained to the students' as those structures or features that enable an organism to survive. While functional adaptation could be regarded as the physiological behaviour of the organisms to carry out certain functions for survival in	The students pay attention and also use the teachers's explanation as further guide to observe the	Observation and communication.

	their environment.	specimen and make further report on their SWH template	
Step IV Adaptation of Xerophyte to their environment	The teacher asks the students to exchange their template with their classmates and explains features that enable Xerophytes to adapt in arid (dry) land thus, 1. Their leaves are reduced to spines/spike to reduce transpiration 2. Their stems are succulent, store water, which serve as a means for water conservation. 3. They have waxy cuticle on their stem to reduce the rate of transpiration. The stems also contain chlorophyll to carry out the functions of photosynthesis 4. Some shed their leaves during dry season 5. Some fold their leaves to minimize the rate of transpiration.	The students exchange their template with their classmates to observe the difference in their report and also listen to the teacher's explanation and corrects some of their mistakes.	Communication
Step V Evaluation	The teacher evaluates the lesson by asking the students the following questions; 1.What is a xerophyte? 2. Give 2 examples of xerophytes? 3. What is the habitat of xerophytes? 4. List 5 adaptive features of xerophytes?	The students answer the questions correctly.	feedback
Step VI Summary	At the end of the practical exercise, a board summary of the entire lesson is given to the students'. SWH student reflection question template is also given to the student to answer as take home assignment.	The students copy the board summary and collects their reflective question template.	Closure

SWH Students' Template for Laboratory Activity

Biology Topic: Adaptation in Xerophytes	Record of observations
Aim of experiment:	
Name of student: Duration of experiment:	
Where was the experiment carried out? Give reason why?	
Identify the specimen placed before you?	
What is the habitat of the specimen?	
Does the specimen have leaves? Why are there no leaves on the specimen?	

What are your general observations about the specimen?	
List 5 adaptive features of the specimen?	
Using the apparatus placed beside the specimen, dissert the specimen and observe the internal part of the specimen?	
What are your observation of the internal part of the specimen?	
Why is the internal part of the specimen the way it is?	
State five (5) ways the specimen can adapt to its habitat?	
Draw and label a diagram of the specimen measuring about 5-8cm	

Exchange your template with your classmate to see the observation or report he/she has made and compare it to your work. You can also discuss and exchange ideas about the topic. This will enable you answer the question on the student reflective question template and broaden your knowledge of the topic.	

SWH Template for Students' Reflection Questions

(Assignment)

BIOLOGY LABORATORY Reflections: What did I learn from the experiment? ……
What are the possible things I can repeat so that I can verify my observations, to notice my mistakes and improve in areas where I have difficulties? What would I have done differently?
How have my ideas changed about carrying out the experiment on my own without the assistance of my class teacher?
Comment on your work compare to that of your classmates?

Based on your understanding, explain in details the benefits of using real life objects as specimen?

……..……
……..

List some of the knowledge/science skills acquired while carrying out the experiments on your own?

……
……

LESSON PLAN FOR CONVENTIONALTEACHING METHOD

Lesson Plan For Week One

Subject: Biology

Class: Senior Secondary School year II

Duration: 80mins

Topic: Stages of development in foods

CONTENT: Stages of development in toads and adaptation of a toad to its natural habitat.

SPECIFIC OBJECTIVE: By the end of the lesson, students should be able to;

1. List the 6 stages in the development of a toad.

2. Describe with the aid of a diagram, the various changes that occur during the development of a toad.

3. Define adaptation.

4. List the general adaptation of a toad to its natural habitat.

5. Explain the functions of these special features and structures that enable the toad adapt to its habitat.

INSTRUCTIONAL MATERIALS: A chart showing the different stages in the development of a toad and adult toad.

ENTRY BEHAVIOUR: Students can identify toads.

INSTRUCTIONAL PROCEDURE:

Set induction:- The teacher places an adult toad in a petric dish and gives it to the students to examine it. The teacher also asks the students to write down their observations.

CONTENT DEVELOPMENT	TEACHER'S ACTIVITY	STUDENT ACTIVITY	TEACHING SKILL
Step I Introduction	The teacher introduces the topic and writes the topic on the board.	The students listen to the teacher and writes down the topic on their workbook.	Communication
Step II Stages of development in	The teacher explains that to the students that there are six stages of	The students observe the chart	Observation

toads	development in a toad. Hangs the chart showing the different stages of development in toad on the board and ask the students to observe the various stages and write down their observation in their workbook.	on the board and writes down their observation.	
Step III Six stages of development in toads	The teacher list the six stages of development in toads as follows: 1. The egg stage 2. The external gill stage 3. The internal gill stage 4. The limb stage 5. The young toad stage 6. The adult toad stage.	The students identify the six stages of development in toads using the chart on the board as a guide and record their findings.	Inference
Step IV Adaptation of a toad to its natural habitat	The teacher defines adaptation for the student. as the ability of an organism to withstand unfavourable environment conditions with the aid of special organs and features. i. Special olfactory organ in the head for smelling. ii. Ability to draw its eyes into a bulge at the roof of its mouth to swallowed its prey and prevents its prey from	The students listen to the teacher and writes down the definition on their workbook.	communication

	escaping. iii. Long tongue attached to the front of its mouth used for capturing its prey iv. Webbed feet for swimming v. Streamlining vi. Body for swimming		
Step v Evaluation	The teacher evaluates the student by asking them the following questions; 1. Define adaptation? 2. List 5 adaptation of a toad to its environment? 3. What are the functions of these features: 1. Special olfactory organ? 2. Long tongue? 3. Webbed feet?	The students answer the questions correctly on their workbook.	Inference and feedback
Step VI Summary	The teacher summarizes the lesson by revising the lesson with the students, moves round to check the students workbook and also encourages the students to ask questions on their area of weakness. The teacher make the necessary corrections and gives the students notes on the topic taught . The teacher also gives the students take home assignment.	The students listen to the teacher, corrects their mistakes and copy their	Closure

		notes.	

Assignment

Plant maize and beans seed in a beaker containing loamy soil and record your day to day observation of the germination of seeds.

Lesson Plan For Week Two

SUBJECT: Biology

CLASS: SS II

DURATION: 80mins

TOPIC: Germination of seeds

CONTENT: Germination of seeds and conditions necessary for germination of seeds

SPECIFIC OBJECTIVES: At the end of the lesson, students should be able to;

1. Define germination
2. Mention the 2 types of germination
3. Explain the process of germination in maize and bean seeds
4. List four conditions necessary for the germination of seeds

ENTRY BEHAVIOUR: The students have planted maize and bean seeds

INSTRUCTIONAL PROCEDURE:

Step 1: Set induction:- The teacher asks the students to place their maize and bean seedlings on the desk.

CONTENT DEVELOPMENT	TEACHER'S ACTIVITY	STUDENT ACTIVITY	TEACHING SKILL

Step I Introduction	The teacher introduces the topic by asking the students to mention some of their observation on germination of seed and writes the topic on the board.	The students list some of the observations made on germination of seeds.	Communication
Step II	Germination of seeds. The teacher defines germination for the students as the process which involves the gradual development of the embryo of the seed into a seedling or young plant. The teacher explains that when conditions are favorable that the seed undergo several changes to develop into seedlings.	The students listen to the teacher and writes down the definition of germination on their workbook.	Communication
Step III Types of germination	The teacher mentions the two types of germination as Epigeal germination: the type of germination in which the cotyledons or seed leaves are carried above the soil surface. This takes place in dicotyledonous plant such as beans, cowpea, groundnut, melon, mango, etc Hypogeal germination is the type of germination in which the	The students listen to the teacher and compare the teacher's explanation to the seedlings on their workstation and writes down their observation.	Observation

	cotyledons, seed leaves or endosperm remain below the soil. This takes place in monocotyledonous plants such as maize, oil palm, guinea corn, millet, wheat, etc. The teacher further explains the process of germination in maize and beans using the seedlings planted by the students for illustration.	The students examine the seedlings on their work station to identify the type of germination.	Inference
Step IV Conditions necessary for the germination of seeds.	The teacher list all the conditions that are necessary for the germination of seeds as: 2. Water and moisture. 3. Air or oxygen 4. Warmth and suitable temperature 5. Enzymes 6. Energy or food 7. Viable seeds The teacher then explain how these conditions help seeds to germinate as	The students listen to the teacher's explanation and compare it to some of the condition they ensured were in place while planting the maize and bean seeds at home.	Inference

	follows; a. Water: Helps to activate the cell, soften the testa or seed coat so that the radical and plumule can come out with ease. b. Air: The seed needs oxygen to carry out respiration where by energy is released for the growth of the seed. c. Warmth: every seed requires optimum temperature to germinate. If below or above this temperature the seed might die. d. Enzymes: These are required in the breaking down of food to release energy. e. Energy or food: There must be food within the seed from which it feeds. f. Viable seeds: For seeds to germinate, it		

Step V Evaluation	must be alive. Damaged seeds by insects, birds or man cannot germinate because they are not viable. The teacher evaluates the lesson by asking the students the following questions; 1. Define germination? 2. Mention 2 types of germination, 3. Explain the process of germination in maize? 4. Explain the process of germination in beans? 5. List 4 conditions necessary for the germination of seeds. 6. State how these conditions affect the germination of seeds? The teacher summarizes the lesson with the students by revising the topic with the students and also	The students answer the questions correctly on their workbook.	Feed back

Step VI summary	answers questions raised by the students. The teacher also give the students take home assignment.	The students listen to the teacher, ask questions on their area of difficulty and note down the corrections made by the teacher	closure

Assignment

The teacher demonstrates the experiment showing the condition necessary for the germination of seeds and asks the students to replicate the experiment in their workbook.

LESSON Plan for Week Three

SUBJECT: Biology

CLASS: S.S. II

DURATION: 80mins

TOPIC: The flower as an organ of reproduction in flowering plants.

CONTENT: Structure of the flower, functions of the floral part of the flower, terms used in describing flowers and placentation in flowering plants.

SPECIFIC OBJECTIVES: By the end of the lesson, students should be able to;

iii. Mention the floral part of a flower.
iv. Give the functions of each of the floral part of the flower.
v. Mention the 3 types of ovary in a flower.
vi. Explain 6 infloresence flower (b) complete (c) complete flower
vii. Give a brief explanation of placentation in flower.

ENTRY BEHAVIOUR: Students are familiar with flowers; they can mention types of flowers and some floral parts in flowers.

INSTRUCTIONAL MATERIALS: Hibiscus flower, pride of Barbados, sun flower, charts showing different kinds of placentation in flowers.

INSTRUCTIONAL PROCEDURE:

Step 1: Set Induction: The teacher shows the students the flowers (hibiscus, sun flower, and pride of Barbados) and asks them to identify them and also mention some of the floral parts they are familiar with.

CONTENT DEVELOPMENT	TEACHERS ACTIVITY	STUDENTS' ACTIVITY	TEACHING SKILL
Step I Introduction	The teacher introduces the topic and writes the topic on the board.	The students writes the topic on their workbook	Communication
Step II Structure of flower	The teacher informs the students that the flower is made up of four floral parts namely; 1. The calyx (sepals) 2. The corolla (petals) 3. The androecium These floral parts are usually arranged in concentric rings, one above	The students identify these floral parts on the specimen on their workstation and write down their observation	Observation

	the other on the receptacle or thalamus		
Step III Functions of the floral parts of a flower	• The calyx: This consists of sepals which are usually green and small. It protects the flower which is in a bud, the sepals are either separated (polysepalous) or joined to form a cup (gamosepalous). • The corolla: They form the second whorl of the flower. Most flowers are either polypetalous (separated petals) or gamopetalous (joined to form a tube). Petals are brightly coloured and scented which attract pollinators such as insect, animals, etc. when both petals look alike, they are collectively known as the perianth, such as in lilies. • Androecium: This is the male reproductive organ of a flower. It consists of stamens, most stamens have long slender stalk called filament and a swollen end called the anther. The filament holds	The student listens to the teacher's explanation and links each floral part of the flower to its functions.	Inference

	or carries the anther while the anther contains pollen grains produce the male gametes that fertilize the ovules. • Gynoecium: This is the female reproductive organ of the flower. It consists of one, few or many carpel is known as a pistil. A pistil consists of ovary, style and stigma. The stigma receives the pollen grains at pollination, the style connects the stigma to the ovary and it is the passage for the pollen tube to reach the ovules. The ovary contains ovules which develop into fruits. The ovules produce the female gametes which develop into seeds.		
Step IV Types of ovary in flower	The teacher explains that there are3 types of ovary in a flower and dissects the flowers used as teaching aid and also ask the students to do the same with flowers on their workstation. 1. Superior ovary: This is when the ovary is placed above the floral parts. For example hibiscus flower, its flower is known as	The students disserts the flower on their workstation following the teachers example and identify the ovary on the flowers given to them and writes down their observation.	Experiment

	hypogynous flower. 2. Half inferior: This is when the ovary lies inside a cup shaped receptacle and other floral parts appear to be attached slightly above it. It is described as a perigynous flower. 3. Inferior ovary: This is when the ovary is placed below the other floral parts. Its flower is known as epigynous		
Step V Terms used in describing a flower	The teacher explains each of the terms used to describe flowers as follows: 1. Inflorescence: Group of flowers attached to a common stalk, e.g. pride of Barbados. 2. Solitary flower: Attached singly either to the leaf axis or to the tip of a branch, e.g. hibiscus flower or pawpaw. 3. Perfect flower: Has both carpel and stamens in it, e.g. pride of Barbados. 4. Imperfect flower: One in which either stamens or carpel are naturally missing, e.g. maize flower. 5. Complete flower: One which has all the four floral parts	The students identify and classify the specimen on their workstation based on the explanation given by the teacher and record their observation.	Classifying and inference.

	of a flower, e.g. hibiscus flower, pride of Barbados, etc. 6. Incomplete flower: One which lacks one or more of the floral parts e.g. maize. 7. Regular flower: All members of the whorl are evenly arranged in their numbers, e.g. hibiscus flower. 8. Irregular flower: All members of the whorl are evenly arranged and some parts are missing, e.g. pride of Barbados. 9. Auxiliary flower: Are borne at the end of the stems or branches. 10. Terminal flower: Are borne at the end of the stems or branches. 11. Monoecious flower: Male and female part are found on same plant, e.g. pawpaw.		
Step VI Placentation in flowering plants	The teacher defines placentation for the students with the aid of the chart showing the different kinds of placentation thus; 1. Marginal placentation: Ovules are attached to the placenta along one margin, e.g. beans, pride of	The students listen to the teacher and write down examples of placentation in flowers on their workbook.	Communication

	Barbados, etc. 2. Free placentation: Ovules are borne on a knob which projects from the base of the ovary, e.g. cana lily. 3. Axile placentation: Ovules are attached to the middle of a syncarpous ovary, e.g. tomato. 4. Basal placentation: Ovules attached to the base of a syncarpous ovary, e.g. sunflower.		
Step VII Evaluation	The teacher evaluates the lesson by asking the students the following questions; 1. Mention the floral parts of the flower? 2. What are the functions of the floral parts? 3. State the three types of ovary in a flower. 4. Write short note on the following; I. Regular flower? II. Irregular flower? III. Draw the diagram of the 4 kinds of placentation?	The students answer the questions correctly on their workbook	Feedback
Step VIII Summary	The teacher summarizes the lesson by revising the entire topic with the students, encourages the students to ask questions on their area of difficulty and makes the necessary corrections	The students answer the questions correctly on their area of difficulties and writes down the corrections made	

		by the teacher.	

Lesson Plan for Week Four

SUBJECT: Biology

DURATION: 80mins

CLASS: S.S.2

TOPIC: Adaptation in xerophytes.

CONTENT: Meaning of xerophytes, structural and functional adaptation in xerophytes.

SPECIFIC OBJECTIVES: At the end of the lesson, students should be able to;

1. Define xerophytes
2. Give 3 examples of xerophytes.
3. Differentiate between structural and functional adaptations in xerophytes.

ENTRY BEHAHIOUR: Students have studied adaptation in toads.

INSTRUCTIONAL MATERIALS: Live specimen of cactus of a prickly pear (optonia spp) and chart showing a mature and joint young prickly pear.

INSTRUCTIONAL PROCEDURE:

Set induction: The teacher set induces the students by reminding them of the previous lesson on adaptations in toads. The teacher also asks the students to state some of the features in toads that enable them survive in their habitat.

CONTENT DEVELOPMENT	TEACHERS' ACTIVITY	STUDENT ACTIVITY	TEACHING SKILL
Step I Introduction	The teacher introduces the topic and writes it on the board.	The students write the topic on their workbook.	Communication
Step II Definition of Xerophytes	The teacher explains that xerophytes are plants which are	The students listen to the teacher's explanation,	Observation

	adapted to survive drought or prolonged dry condition in their habitat. The teacher gives students some examples of xerophytes as; 1. Prickly pear 2. Barrel cacti 3. Aloe vera, etc The teacher also shows the students live specimen of cactus plant of a prickly pear for identification and hangs the chart showing a mature and young growing joint of a prickly pear cactus.	observe the live specimen of prickly pear and writes down their observation on their workbook.	
Step III Structural and functional adaptations in xerophytes	The teacher explains structural adaptation as those structures or features that enable an organism survive in its habitat. The teacher explain functional adaptation as the physiological behavior of the organism to carry out certain functions for survival in its environment. The teacher then asks the students to differentiate between structural and functional adaptation.	The students listen to the teacher's explanation and use the example given by the teacher to differentiate between functional and structural adaptation.	Inference
Step IV Adaptation of xerophytes to their environment.	The teacher gives the students the following features that enable xerophytes to adapt to arid land as; i. Their leaves are reduced to spine/spike to reduce	The students identify these features on the specimen given to them and write down their observation.	experiment

	transpiration. ii. Their leaves are succulent, store water which serves as a means for water conservation. iii. They have waxy cuticle on their stem to reduce the rate of transpiration. iv. The stem contains chlorophyll to carry out the process of photosynthesis. v. Some shed their leaves during dry season. vi. Some fold their leaves during dry season to minimize transpiration.		
Step V Evaluation	The teacher evaluates the lesson by asking the students the following questions; 1. Define xerophytes? 2. Give 3 examples of xerophytes? 3. Differentiate between structural and functional adaptations in xerophytes? 4. State 3 features that enable xerophytes to survive in their environment?	The students answer the questions correctly on their workbook.	Feedback

Step VI Summary	The teacher summarizes the lesson by revising the entire topic with the students. Encourages the students to ask questions and makes the necessary corrections.	The students ask questions on their area of difficulty and notes down corrections made by the teacher.	closure

APPENDIX G

CALCULATIONS FOR RELIABILITY COEFFICIENT (R) FOR 40 STUDENTS ON HBAT

S/N	X	$(X-\bar{X})$	$(X-\bar{X})^2$	S/N	X	$(X-\bar{X})$	$(X-\bar{X})^2$
1	35	7.5	56.25	21	25	-2.5	6.25
2	30	2.5	6.25	22	10	-17.5	306.25
3	25	-2.5	6.25	23	15	-12.5	156.25
4	40	12.5	156.25	24	25	-2.5	6.25
5	35	7.5	56.25	25	35	7.5	56.25
6	10	-17.5	306.25	26	20	-7.5	56.25
7	25	-2.5	6.25	27	35	7.5	56.25
8	15	-12.5	156.25	28	30	2.5	6.25
9	45	17.5	306.25	29	40	12.5	156.25
10	20	-7.5	56.25	30	35	7.5	56.25
11	15	-12.5	156.25	31	25	-2.5	6.25
12	35	7.5	56.25	32	30	2.5	6.25
13	20	-7.5	56.25	33	25	-2.5	6.25
14	45	17.5	306.25	34	30	2.5	6.25
15	30	2.5	6.25	35	35	7.5	56.25
16	30	2.5	6.25	36	30	2.5	6.25
17	10	-17.5	306.25	37	30	2.5	6.25
18	15	-12.5	156.25	38	30	-2.5	6.25
19	35	7.5	56.25	39	25	-2.5	6.25
20	30	2.5	6.25	40	30	2.5	6.25

$\bar{X} = 27.63$

$\sum (X - \bar{X})^2 = 3199.38$

$$d = \sqrt{\frac{(x-\bar{x})^2}{N}} = \sqrt{\frac{3199.38}{40}} = 8.9$$

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

Where,

K = number of items = 40

= mean score = 27.63

d = standard deviation = 8.9

$$r = \frac{40(8.9)^2 - 27.63\ (40 - 27.63)}{8.9^2(40-1)}$$

$$r = \frac{2857.597}{3089.19} = 0.91$$

APPENDIX H

CALCULATIONS FOR RELIABILITY COEFFICIENT (R) FOR 40 STUDENTS ON SPSAT

S/N	X	$(X-\bar{X})$	$(X-\bar{X})^2$	S/N	X	$(X-\bar{X})$	$(X-\bar{X})^2$
1	30	7.38	54.4644	21	25	-2.62	6.8644
2	30	2.38	5.6644	22	10	-17.62	310.4644
3	20	-2.62	6.8644	23	15	-12.62	159.2644
4	30	12.38	153.2644	24	25	-2.62	6.8644
5	30	7.38	54.4644	25	15	7.38	54.4644
6	10	-17.62	310.4644	26	20	-7.62	58.0644
7	25	-2.62	6.8644	27	30	7.38	54.4644
8	15	-12.62	159.2644	28	30	2.38	5.6644
9	25	17.38	302.0644	29	20	12.38	153.2644
10	20	-7.62	58.0644	30	35	7.38	54.4644
11	15	-12.62	159.2644	31	25	-2.62	6.8644
12	35	7.38	54.4644	32	30	2.38	5.6644
13	20	-7.62	58.0644	33	25	-2.62	6.8644
14	20	17.38	302.0644	34	30	2.38	5.6644
15	30	2.38	5.6644	35	25	7.38	54.4644
16	30	2.38	5.6644	36	30	2.38	5.6644
17	10	-17.62	310.4644	37	25	2.38	5.6644
18	15	-12.62	159.2644	38	25	2.38	5.6644
19	35	7.38	54.4644	39	25	-2.62	6.8644
20	30	2.38	5.6644	40	10	2.38	6.8644

$\bar{X} = 23.75$

$\sum (X - \bar{X})^2 = 2087.5$

$$d = \sqrt{\frac{(x-\bar{x})^2}{N}} = \sqrt{\frac{2087.5}{40}} = 7.22$$

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

Where,

K = number of items = 40

= mean score = 23.75

d = standard deviation = 7.22

$$r = \frac{40(7.22)^2 - 23.75(40 - 23.75)}{7.22^2(40-1)}$$

$$r = \frac{1699.1985}{2033.0076} = 0.83$$

APPENDIX I
TRAINING NOTES FOR TEACHERS' ON HOW TO USE SCIENCE WRITING HEURISTIC TEACHING APPROACH IN THE TEACHING OF BIOLOGY IN SENIOR SECONDARY SCHOOLS.

The researcher trained four senior secondary year two (SS-2) Biology teachers for the period of one week (two hours on Mondays, Wednesdays and Fridays). The researcher introduced the experimental group teachers to the use of science writing heuristics by presenting to them the science writing heuristics template and gives them the reason for the introduction of the use of this approach in the teaching of biology and engages the teachers in a mock teaching exercise after the training to access their knowledge in the use of science writing heuristics approach in the teaching of biology. The teachers from the control group school where also trained using their own conventional teaching method lesson plan.

Procedure:

DAY 1: Advantages and disadvantages of the conventional lab- write-up.

(a) Limitations in the use of the conventional laboratory write-up

The conventional laboratory write-up (lecture method, teacher centred method, etc.) encourages/reinforce science process skills and teach the students how to work together for a common goal, without additional guiding questions. This format is not designed for the students to generate meaning of what occurred or are the students expected to use their evidence to make a claim.

Conventional Laboratory write up Format

4. Title
5. Purpose: - what questions do we want to answer?

6. Procedure: - how do we find out the answer?
7. Data: - observations and measurements
8. Results: - summary of the data (graph, chart and tables)
9. Conclusion: - how did our result compare to our purpose?

The teacher directs the instruction, materials and questions and conclusions are provided to the students. in this approach, the students follow all the procedures using a prescribed step by step manual and document their observation. They see the product of their observations produced by the experiment, but miss the benefits of reasoning through the "why" of the experiment.

The conventional laboratory write-up is compartmentalized and as such, it fails to make the laboratory experience personal for the students, because the laboratory experiment has been pre-planned under headings. For example, purpose, hypothesis, experimental design, data and conclusion. The conclusion doesn't answer the question of whether their hypothesis was correct or not. The conventional laboratory write-up also fails to give room for students to carry out the experiment on their own thereby limiting their acquisition of science process skill. This also affects students' achievements in biology as students are not able to relate biology concepts learnt to answering of examination questions.

DAY II

Why the Use of Science Writing Heuristics?

The researcher introduces to the experimentall group teachers the science writing heuristics teaching approach by explaining to the teachers the meaning of science writing heuristics and how it is used.

Definition and Meaning of Science Writing Heuristics: The word heuristics simply means to discover, the science writing heuristics (SWH) is a tool to improve students' experience specifically in laboratory settings. SWH is a writing –to –learn process that provides students with opportunity to link new knowledge to previous knowledge/information, generate meaning from their laboratory experiences, challenge misconceptions with cognitive conflicts, socially interact with their peers throughout the entire process and utilize discourse and writing to clear up any confusion.

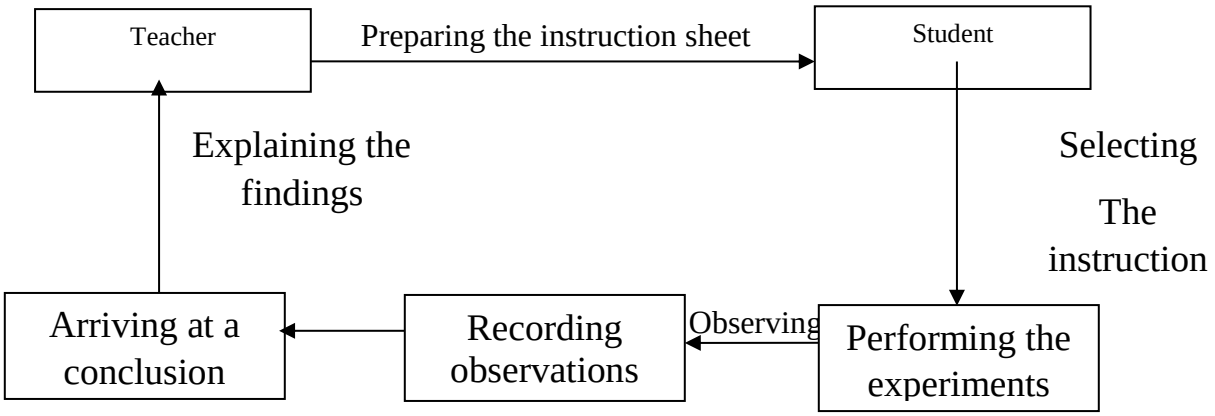
The SWH encourages students to develop reasoning skills, become scientifically literate through writing and also acquire science process skills and thereby improve on their achievement in biology. The SWH teaching approach is suitable for teaching practical orientated topics in science, in this method, the student is put in place of an independent discoverer. That is, no help is provided by teacher in this method, the teacher introduces the topic, presents the specimen, apparatus and the questions to the students, then stands aside while the students' discover the answers, that is, placing the students' as far as possible in the attitude of the discoverer (finding out truth for themselves). The method requires the students' to solve a number of problems experimentally, the experiment starts with questions in other to find answers, the students' solves the problem and clarify ideas to see what happens.

STEP II: the researcher presents the science writing heuristics template to the biology teachers. The researcher explains how the teachers can put to use the science writing heuristics template in teaching biology.

Procedure:

The teacher takes the students' to the laboratory, writes the new topic on the board, gives each student a copy of the SWH students' template for the topic. The lesson begins with the students' carrying out the experiments, the students' carryout the experiment with instructions (hints on the topic under discussion) using the specimen and apparatus provided for the experiment. The teacher is to stand aside and observe what the students' are doing, only making necessary corrections when students' are going astray from the desired aim of the experiment. The students are to carry out the experiment as written in their SWH template and record their findings, use the results of their findings to answer the questions written on their SWH template. Each student is to compare their report with that of their classmates and exchange ideas on the experiment, this helps them to learn new ideas from their classmates and also raise questions on the topic under discussion. The students' report is evaluated by the teacher to find out areas where students' are having difficulties in understanding the concept to be taught, from the teacher's observations of the students learning difficulties, the teacher begins the lesson, making sure that emphasis are made on the areas where students are having difficulties.

Model of SWH teaching approach



-

The researcher explains to the teachers step by step on how it is used, using a biology concept as an example. For example, important points that must be observed while answering practical biology examination questions (measurement of diagram, magnification, drawing of lines e.t.c). The researcher also encourages the biology teachers to ask questions on areas where they are having difficulty, while the researcher explains to them using lucid examples.

STEP III: importance for introducing the use of science writing heuristics approach in the teaching of biology. The researcher highlights the importance and benefits of using science writing heuristics in the teaching of biology

g. The SWH format allows students' guided by the teacher to determine their own investigative questions.
h. Fosters within students an initial interest in the investigation and helps them develop scientific attitudes.
i. By asking their own questions, students assume ownership of their learning, which leads to increase the chances of students' involvement in carryout their own investigation.
j. Creates learning experiences that allows the students to learn about a concept in a way that is important to him or her.
k. Fosters the students writing skills and makes them psychologically sound, because SWH teaching approach is based on learning by doing.
l. Leads to acquisition of science process skill.

m. Helps students to improve on their studies, thereby leading to better achievement in biology.
n. It develops the habit of self-learning and self-directions in the students'.
o. It foster cordial relations between the students' and the teacher and between students and their classmates.

DAY III: Mock teaching: the researcher gives the biology teachers prepared lesson plan and lesson note to carry out the micro teaching while the researcher assesses the teachers and makes the final selection for teachers to be used in carrying out the teaching of biology using the science writing heuristics in the selected schools for the study.

APPENDIX J

Science Education Department,

Nnamdi Azikiwe University,

Awka,

Anambra State.

Dear Validator,

REQUEST FOR VALIDATION

I, Irede Elohor Heuristic, a PhD student of the above named department in Biology option is carrying out a research on 'Effect of Science Writing Heuristics on secondary school students' Achievement and Acquisition of Science process skill in Biology.

I humbly request that you use your experience and expertise to proof read, cross-check and validate these instruments for my study.

Specifically, the study aims at determining the effect of:

1. Science writing heuristics (SWH) on biology achievement of secondary school students.

2. Science writing heuristics (SWH) on biology achievement of male and female secondary school students.

3. Science writing heuristics on the acquisition of science process skills by secondary school biology students'.

4. Science writing heuristics on the acquisition of science process skills by secondary school biology students relative to gender.

5. Interaction between gender and teacher method as measured from their mean achievement scores in biology.

6. Interaction between gender and teacher method as measured from their mean science process skills scores in biology.

The research is guided by the following research questions:

1. What are the mean and standard deviation achievement scores of students taught biology using science writing heuristics (SWH) teaching approach and those taught using the conventional method?

2. What are the mean and standard deviation achievement scores of male and female students taught biology using science writing heuristics teaching approach?

3. What are the mean and standard deviation scores of students in the science process skills of observing, experimenting, inferring, classifying and communicating, those taught biology using science writing heuristics (SWH) teaching approach and those taught using the conventional method?

4. What are the overall mean and standard deviation scores of students in science process skills of those taught biology using science writing heuristics (SWH) teaching approach and those taught using the conventional method?

5. What are the mean and standard deviation scores of male and female students in the science process skills of observing, experimenting, inferring, classifying and communicating, those taught biology using science writing heuristics (SWH) teaching approach?

6. What are the overall mean and standard deviation of science process skills scores of male and female students taught biology using science writing heuristics teaching approach?

Sir/Ma, I will be very grateful if you can grant me this request.

Thanks for your cooperation.

Yours faithfully,

Elohor Heuristic Irede

INSTRUMENT VALIDATION REPORT

Validation of instrument on the topic:

Effects of Science writing heuristics on secondary school students' achievement and acquisition of science process skill in biology.

This is to certify that I Dr E. C. Otigbo validated the above mentioned instrument and made corrections/recommendations in the following areas:

(1) The interaction effect should be in the purpose not in research qn

(2) Go through the instrument (BAT) and do all the editorial corrections identified

After the amendments, I considered the instruments fit/~~unfit~~ for the study which it is designed for.

Signature: [signature]

Date: 24/10/2016

INSTRUMENT VALIDATION REPORT

Validation of instrument on the topic:

Effects of Science Worthy Heuristics on Secondary School Student's Achievement and Acquisition of Science Process Skill in Biology

This is to certify that I, MR OGBEDO, S. K. validated the above mentioned instrument and made corrections/recommendations in the following areas;

(1) Typographical errors in the instrument
The candidate should check for typographical errors in the instrument and effect the necessary corrections

(2) Corrections noted in the instrument
The candidate should effect the corrections noted in the instrument

After the amendments, I considered the instruments fit/~~unfit~~ for the study which it is designed for.

Signature: [signature]

Date: 30/09/16

INSTRUMENT VALIDATION REPORT

Validation of instrument on the topic:

Effects of Science writing heuristics on Secondary School Students achievement and acquisition of Science process skill in biology

This is to certify that I Dr Patrick Ejelu validated the above mentioned instrument and made corrections/recommendations in the following areas;

1) Reconstruct the hypothesis

2) Effect the necessary corrections identified.

After the amendments, I considered the instruments fit/~~unfit~~ for the study which it is designed for.

Signature:

Date: 23/9/2016

INSTRUMENT VALIDATION REPORT

Validation of instrument on the topic:

Effects of Science Writing Heuristics on Secondary School Students' Achievement and Acquisition of Science Process Skills in Biology

This is to certify that I, MR. OLUWATAYO G. validated the above mentioned instrument and made corrections/recommendations in the following areas:

1. The candidate should provide clear cut answers to the issues raised in the instruments
2. The candidate should effect corrections where necessary & shown in the instrument.

After the amendments, I considered the instruments fit/unfit for the study which it is designed for.

Signature: ...

Date: 18/07/2016

SPSS OUTPUT

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Pretest ACH Exp.	101	30	5	35	2055	20.35	7.323	53.629
Pretest ACH CTRL	106	30	5	35	2195	20.71	7.350	54.018
Posttest ACH Exp.	101	40	45	85	6089	60.29	7.554	57.067
Posttest ACH CTRL	106	20	25	45	3720	35.09	6.546	42.848
Pretest ACH Male	51	30	5	35	1080	21.18	7.182	51.588
Pre ACH Female	50	25	5	30	975	19.50	7.440	55.357
Posttest ACH male	51	30	45	75	3049	59.78	7.567	57.253
Posttest ACH Female	50	40	45	85	3040	60.80	7.584	57.510
Pretest SPS Exp.	101	17	14	31	2123	21.02	4.096	16.780
Pretest SPS CTRL	106	18	13	31	2179	20.56	4.012	16.097
Posttest SPS Exp.	101	43	34	77	5897	58.39	9.390	88.179
Posttest SPS CTRL	106	20	26	46	3783	35.69	4.528	20.502
Pretest SPS Male	51	12	14	26	1049	20.57	3.263	10.650
Pre SPS Female	50	17	14	31	1074	21.48	4.790	22.949
Posttest SPS male	51	39	38	77	2919	57.24	9.131	83.384
Posttest SPS Female	50	41	34	75	2978	59.56	9.596	92.088
Valid N (listwise)	50							

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Pretest (Observing) EG	101	21.00	12.00	33.00	2081.00	20.6040	4.56964	20.882
Pretest (Observing) CG	106	30.00	5.00	35.00	2151.00	20.2925	5.81454	33.809
Pretest (Experimenting) EG	101	34.00	12.00	46.00	1958.00	19.3861	5.95814	35.499
Pretest (Experimenting) CG	106	25.00	10.00	35.00	1989.00	18.7642	5.73469	32.887
Pretest (Inferring) EG	101	34.00	12.00	46.00	2010.00	19.9010	5.70001	32.490
Pretest (Inferring) CG	106	36.00	10.00	46.00	2160.00	20.3774	7.47243	55.837
Pretest (Classifying) EG	101	30.00	5.00	35.00	2071.00	20.5050	7.14090	50.992
Pretest (Classifying) CG	106	30.00	5.00	35.00	2055.00	19.3868	6.92486	47.954
Pretest (Communicating) EG	101	25.00	5.00	30.00	1974.00	19.5446	7.16593	51.350
Pretest (Communicating) CG	106	25.00	10.00	35.00	1990.00	18.7736	6.04000	36.482
Posttest (Observing) EG	101	51.00	34.00	85.00	6093.00	60.3267	8.38822	70.362
Posttest (Observing) CG	106	20.00	25.00	45.00	4050.00	38.2075	6.66150	44.376
Posttest (Experimenting) EG	101	40.00	35.00	75.00	5607.00	55.5149	6.58424	43.352
Posttest (Experimenting) CG	106	27.00	18.00	45.00	3704.00	34.9434	4.34211	18.854
Posttest (Inferring) EG	101	50.00	35.00	85.00	6065.00	60.0495	9.14153	83.568
Posttest (Inferring) CG	106	25.00	21.00	46.00	3326.00	31.3774	7.31398	53.494
Posttest (Classifying) EG	101	30.00	45.00	75.00	6595.00	65.2970	5.95071	35.411

Posttest (Classifying) CG	106	40.00	25.00	65.00	3804.00	35.8868	8.38516	70.311
Posttest (Communicating) EG	101	35.00	40.00	75.00	6360.00	62.9703	6.63996	44.089
Posttest (Communicating) CG	106	20.00	25.00	45.00	3787.00	35.7264	7.21445	52.048
Valid N (listwise)	101							

Between-Subjects Factors

		Value Label	N
Gender	0	female	101
	1	male	106
Method	0	Science Writing Heuristics	101
	1	Conventional Method	106

Tests of Between-Subjects Effects

Dependent Variable: Post achievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	32868.826[a]	4	8217.206	163.337	.000
Intercept	51810.552	1	51810.552	1029.863	.000
PreAch	2.025	1	2.025	.040	.841
Gender	41.222	1	41.222	.819	.366
Method	32766.762	1	32766.762	651.321	.000
Gender * Method	1.080	1	1.080	.021	.884
Error	10162.256	202	50.308		
Total	507845.000	207			
Corrected Total	43031.082	206			

a. R Squared = .764 (Adjusted R Squared = .759)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: Post achievement

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
47.700[a]	.493	46.728	48.673

a. Covariates appearing in the model are evaluated at the following values: Pre achievement = 20.53.

2. Gender

Dependent Variable: Post achievement

Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
female	48.147[a]	.706	46.755	49.539
male	47.254[a]	.689	45.894	48.613

a. Covariates appearing in the model are evaluated at the following values: Pre achievement = 20.53.

3. Method

Dependent Variable: Post achievement

Method	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Science Writing Heuristics	60.295[a]	.706	58.903	61.687
Conventional Method	35.106[a]	.690	33.746	36.466

a. Covariates appearing in the model are evaluated at the following values: Pre achievement = 20.53.

4. Gender * Method

Dependent Variable: Post achievement

Gender	Method	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
female	Science Writing Heuristics	60.814[a]	1.006	58.831	62.797
	Conventional Method	35.480[a]	.994	33.519	37.441

male	Science Writing Heuristics	59.776[a]	.994	57.815	61.736
	Conventional Method	34.732[a]	.957	32.846	36.618

a. Covariates appearing in the model are evaluated at the following values: Pre achievement = 20.53.

Between-Subjects Factors

		Value Label	N
Gender	0	female	101
	1	male	106
Method	0	Science Writing Heuristics	101
	1	Conventional Method	106

Tests of Between-Subjects Effects

Dependent Variable: Posttest SPS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	26925.275[a]	4	6731.319	128.008	.000
Intercept	16927.627	1	16927.627	321.909	.000
PreSPS	2.256	1	2.256	.043	.836
Gender	88.080	1	88.080	1.675	.197
Method	26726.283	1	26726.283	508.248	.000
Gender * Method	31.733	1	31.733	.603	.438
Error	10622.203	202	52.585		
Total	490871.000	207			
Corrected Total	37547.478	206			

a. R Squared = .717 (Adjusted R Squared = .711)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: Posttest SPS

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
47.082[a]	.504	46.088	48.077

a. Covariates appearing in the model are evaluated at the following values: Pretest SPS = 20.78.

2. Gender

Dependent Variable: Posttest SPS

Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
female	47.736[a]	.722	46.312	49.160
male	46.429[a]	.705	45.038	47.819

a. Covariates appearing in the model are evaluated at the following values: Pretest SPS = 20.78.

3. Method

Dependent Variable: Posttest SPS

Method	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Science Writing Heuristics	58.472[a]	.722	57.048	59.896
Conventional Method	35.693[a]	.705	34.302	37.084

a. Covariates appearing in the model are evaluated at the following values: Pretest SPS = 20.78.

4. Gender * Method

Dependent Variable: Posttest SPS

Gender	Method	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
female	Science Writing Heuristics	59.518[a]	1.029	57.489	61.548
	Conventional Method	35.954[a]	1.016	33.950	37.957
male	Science Writing Heuristics	57.426[a]	1.016	55.423	59.429
	Conventional Method	35.432[a]	.978	33.503	37.360

a. Covariates appearing in the model are evaluated at the following values: Pretest SPS = 20.78.