EFFECTS OF INQUIRY-BASED LEARNING ON ACQUISITION OF SCIENCE PROCESS SKILLS AND ACHIEVEMENT IN BIOLOGY AMONG SECONDARY SCHOOL STUDENTS IN WARENG SUB-COUNTY, KENYA

BY

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DECLARATION

Declaration by the candidate

This thesis is my original work and has not been submitted for any academic award in any institution; and shall not be reproduced in part or in full, or in any format without prior written permission from the author and/or University of Eldoret

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DEDICATION

This thesis is dedicated to the University of Eldoret for starting the Doctor of Philosophy programme in Science Education, the Head of Department Science Education, University of Eldoret and all my lecturers.

ABSTRACT

This study investigated the effects of Inquiry-based learning (IBL) in Biology students' acquisition of Science Process Skills (SPS) and achievement among Form three students in Wareng Sub-County of Kenya. The purpose of the study was to determine the effect of IBL on Biology students' acquisition of SPS and achievement. The main objective of the study was to determine the extent to which IBL affects the acquisition of SPS and impacts on achievement among Form three Biology students in Wareng Sub-County of Uasin-Gishu County, Kenya. The study was guided by the constructivist learning theory, derived from the works of Piaget (1973) and Vygotsky (1978). The study was based on a pragmatist philosophy and used Solomon fourfold non-equivalent group design as a quasi-experiment. The study variables were independent variable – IBL and dependent variables were acquisition SPS and achievement in Biology. The study sample comprised 220 Form three students representing a population of 2,594 students. Stratified, systematic and simple random sampling was used to obtain the study sample. Selected students' responded to a Biology Science Process Skills Questionnaire (BSPSQ) which sought to obtain views from learners on IBL. Students were also exposed to two sets of Biology SPS Achievement Test (BSPSAT) – Pre-test and Post-test – so as to establish their achievement. A Biology SPS Observation Checklist (BSPSOC) was used to record observations on application of SPS made during the study. Data was coded, collated and analysed using the computer software of Statistical Package of Social Sciences (SPSS) version 20. Qualitative and quantitative data was presented using tables (frequency and percentages) and graphs. Independent samples *t*-test and both one-way and two-way Analysis of Variance (ANOVA), was used to compare the achievement of the experimental and control groups and also examine the interaction effect between IBL and gender on achievement. The study established a significant difference between students taught using IBL and those taught using TL. The study established that students taught by IBL had higher levels of acquisition of SPS and higher achievement when compared with those taught using TL. The study also established that there was an interaction effect between IBL and gender on achievement. The study concluded that IBL is an effective teaching method on acquisition of SPS and achievement in Biology subject when compared to TL. It is anticipated that the findings of this research will be useful to secondary school Biology teachers, Biology curriculum developers, policy makers in education and other stakeholders in the education sector as relates to effectiveness of IBL on the acquisition of SPS and achievement in Biology. The study also provides suggestions for further research.

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LIST OF ABBREVIATIONS AND ACRONYMS

ATC21: Assessment and Teaching of 21st Century Skills

ANOVA: Analysis of Variance

BSPSOC: Basic Science Process Skills Observation Checklist

BSPS: Basic Science Process Skills

BSPSQ: Biology Science Process Skills Questionnaire

BSPSAT: Biology Science Process Skills Achievement Test

CEMASTEA: Centre for Mathematics, Science and Technology Education in Africa

DNA: Deoxyribose Nucleic Acid

EACEA: Education Audiovisual and Culture Executive Agency

5E: Engagement, Exploration, Explanation, Elaboration and Evaluation

GoK: Government of Kenya

GTA: Graduate Teaching Assistant

IBL: Inquiry – Based Learning

INSET: In Service Education and Training.

ISPS: Integrated Science Process Skills

KCSE: Kenya Certificate of Secondary Education

KICD: Kenya Institute of Curriculum Development

KIE: Kenya Institute of Education

KNEC: Kenya National Examination Council

MoE: Ministry of Education

MoEST: Ministry of Education, Science and Technology

n.d: no date

NACOSTI: National Commission of Science, Technology and Innovation

NRC:	National Research Council
OECD:	Organization of Economic Co-operation and Development
P21:	Partnership for 21st Century Skills
RoK:	Republic of Kenya
SCEO:	Sub- County Education Office
SCSO:	Sub- County Statistics Office
SDG(s):	Sustainable Development Goal(s)
SMASE:	Strengthening of Mathematics and Science Education
SPS:	Science Process Skills
SPSS:	Statistical Package for Social Sciences
TL:	Traditional Learning
UN:	United Nations
UNDP:	United Nations Development Programme
UNESCO:	United Nations Educational, Scientific and Cultural Organization
WHO:	World Health Organisation
WSCSSPJE:	Wareng Sub-county Secondary School Pentagon Joint Examination

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DEFINITIONS OF OPERATIONAL TERMS

Inquiry-Based learning (IBL): Learner-centred method of instruction where learners learn through investigation of problems so as to develop knowledge. Learners are actively engaged and they construct their own knowledge from previous knowledge.

Traditional Learning (TL): Teacher-centred method of instruction where the teacher presents knowledge as facts where students' prior experiences are not regarded as important. The teacher is the active participant while the students are passive recipients of knowledge and participate minimally in the learning process.

Achievement: Status of a student with regard to attained SPS or Biological knowledge measured by the mean scores in the BSPSAT.

Acquisition: Ability to carry out a task that employs Science Process Skills (SPS) such as observing, classifying, measuring, communicating, inferring, interpreting data, controlling variables, defining operationally, hypothesising, experimenting, predicting and creating models.

Gender: The socially constructed roles, behaviours, activities, and attributes that give a given society considers appropriate for men and women (WHO, 2011).

Gender equality: It refers to the notion that males and females have equal opportunity to access education and other rights to facilitate realisation of potential (Katuri, 2013).

Gender equity: Refers to the achievement of gender equality by fair treatment of males and females.

Gender Disparity: It is the gap between boys and girls as indicated by achievement in BSPSAT.

Gender parity: Refers to the proportional representation of males and females in an education system.

Science Process Skills: These are the skills that are used by learners to help them acquire and understand biological knowledge. This study focused on the following SPS: observing, classifying, communicating, measuring, predicting, inferring, controlling variables, defining operationally, hypothesising, interpreting data, experimenting and creating models.

Biology: Science subject taught at secondary school level. that deals with the study of living things

Students: Form three Biology students that were used in the study.

Mixed day school: Secondary schools in which boys and girls learn together, students come from home in the morning and go back home at the end of the school's day's programme.

CHAPTER ONE

INTRODUCTION TO THE STUDY

1.1 Overview of the Chapter

This chapter covers an introduction to the study. It outlines the theoretical background, statement of the problem, purpose, objectives, questions that guided the study, hypotheses, justification, significance, assumptions, scope, limitation, conceptual framework, definition of operational terms and chapter summary.

1.2 Background of the Study

Globally there is still a challenge on establishing which instructional approach shall equip students with both the knowledge and skills required for this 21st century. According to the Student Achievement Division (2013) of the United States of America, educators worldwide encounter the daunting challenge and responsibility of winning students over while learning in order for them to develop the skills and knowledge needed to survive in today's world. Further, educators raise questions on how necessary skills can be instilled in learners and provide them with opportunities to move beyond being passive recipients of knowledge so as to become knowledge builders capable of creating innovative solutions to problems. The concern is which instructional pedagogy will play a role in equipping learners with the requisite knowledge, skills and dispositions to solve the problems of the 21st century (Student Achievement Division, 2013)?

Teaching approaches are ways through which knowledge and skills are presented to learners. These approaches may either be teacher centred, student centred or media-based. Therefore, the pedagogical approaches that are applied for learning in the 21st century should provide adaptability for both the teacher and student in terms of their roles during the learning process (Nuangchalerm, 2014). These approaches should help students develop Science Process Skills (SPS) and other necessary skills to survive in this rapidly changing world rich in information technology (Holbrook & Rannikmäe, 2009). Science process skills can be defined as cognitive and psychomotor skills employed in problem solving and inquiry learning (Akinbobola & Afolabi, 2010).

Biology is a practical subject which requires the teacher to develop scientific skills among the learners. Once these skills are internalised by the learners, they can be used in their daily life (MoE, 2003; Ngesu, Gunga, Wachira & Kaluku, 2014). For effective teaching and learning to take place, the approach adopted by a teacher is paramount (Muraya & Kimamo, 2011) hence, teachers are recommended to use teaching and learning approaches that will engage learners to develop requisite skills for application in their environment. The study of Biology aims at equipping the learner with the knowledge, concepts, attitudes and skills which are necessary for controlling and preserving the environment (MoE, 2003).

According to the United Nations report (2015), environmental sustainability is a key sustainable development goal (SDG) that requires an urgent address by all nations because survival of life on the planet earth is at risk. Biology is a subject that can contribute useful knowledge applicable in sectors of the economy such as health, agriculture, environment, education and industry. In agriculture for example, it has been applied in plant and animal breeding to produce disease-resistant, high-yielding crops and animals thus promoting food security for the ever growing population. Biology is the precursor of bio-technology which is a tool for industrial and technological development (MoE, 2003). In medicine, Biology has enabled preventive and curative measures to ensure a healthy and productive population. In industry, it has been applied in manufacturing of drugs and agrochemicals, breweries, bakeries and milk processing. Therefore, Biology as a discipline is consistent with the SDGs on food security and good health. Knowledge in Biology has also enabled humanity to appreciate human beings as part of the broader community of living organisms and understand their role in managing of biodiversity and environmental conservation (UNDP, 2015; UNESCO, 2010) due to environmental challenges such as global warming, pollution, environmental degradation including desertification, climate change and population explosion (UNDP, 2015; UNESCO, 2010; UN, 2015). Some of the general objectives of the secondary school level Biology subject syllabus that emphasize on skill development are:

1. To develop positive attitudes and interest towards Biology and the relevant practical skills, 2. To demonstrate relevant technical skills and scientific thinking necessary for economic development and 3. To acquire a firm foundation of relevant knowledge, skills and attitudes for further education and training in related scientific fields (MoE, 2003, p. 2).

The term ‘‘inquiry’’ dates back to the middle of the 13th century and it originates from the Latin word *inquīrere* which literally means “to seek for” (Alberta Education, 2010). In Science, it refers to the capacity of students to plan and carry out scientific activities that involve investigations (National Research Council-NRC, 2000). In instruction it is construed as the teaching and learning strategies that enable concepts to be mastered through investigation and practical work (ibid). Inquiry therefore can be considered as a process that actively engages learners’ by creating interest through challenges that allow them to connect their world hence developing knowledge using reasoning and thinking skills (National Research Council-NRC, 1996; Nworgu & Otum, 2013). Inquiry learning approach presents merits such as allowing students to construct their own knowledge from observations made (OECD, 2006), experience authentic learning (Saunders-Stewart, Gyles & Shore, 2012), increased engagement for deeper learning hence better conceptualisation of knowledge and skills (Spronken-Smith, 2010), improved cognitive development (Harlen & Allende, 2009) and achievement of positive learning outcomes (Spronken-Smith *et al*., 2011). Inquiry can be categorised as structured, guided or open inquiry (Staver & Bay, 1987).

The global trend of learning in schools is moving away from the traditional learning methods towards learner-centred approaches which require students to be "active constructors of knowledge" (Chu, Wong, Lee, Chow & Ng, 2011, p. 133). Studies (Achor & Agamber, 2016; Githae, Keraro & Wachanga, 2015; Muraya & Kimamo, 2011) that have focused on student-centred methodologies have presented findings that advocate for their espousal. These studies have shown eminence for these methodologies because of the student learning outcomes that they promote. These learning outcomes include student characteristics such as self esteem, interest, attitudes and motivation which are paramount for skills acquisition.

Some of the teaching methods that have been investigated to determine their effectivenessc in Biology include: practical-oriented method and its effects on achievement and acquisition of SPS (Achor & Agamber, 2016; Nwagbo & Chukelu, 2011), effect of experiential learning on academic achievement (Okoli & Okechukwu, 2014), effect of concept mapping on achievement and knowledge retention (Ahmad & Munawar, 2013; Ajaja, 2013; Githae, Keraro & Wachanga, 2015; Sakiyo & Waziri, 2015), outcome of peer tutoring on achievement (Ezenwosu & Nworgu, 2013), effect of computer based learning (Ayotola & Abiodun, 2010; Olakekan & Oludipe, 2016) and cooperative learning (Muraya & Kimamo, 2011; Nneka, 2015) on achievement.

Studies conducted on IBL have shown that it increases students' enthusiasm, motivation and interest in Biology (Miller, 2014), Physics (Njoroge, Changeiywo & Ndirangu, 2014) and general Science (Ofsted, 2008). In professional development, findings in a study conducted by Hughes and Ellefson (2013), observed that Biology graduate training assistants (GTAs) improved their quality of teaching when exposed to inquiry teaching methods as opposed to traditional learning methods. Studies so far conducted on IBL have illustrated scarce empirical evidence on the effects of IBL on students' acquisition of SPS and achievement in Biology.

Despite the findings of studies which gave precedence to the inquiry method, the prevailing teaching method to basic education is traditional learning. Teachers transmit factual knowledge to students through lectures and textbooks (Aladejana, 2008; AT21CS, n.d; Friesen & Scott, 2013; OECD, 2009). Kenya is not excluded, the Ministry of Education Science and Technology (MoEST) echoes similar sentiments and has observed that teachers continue to use the traditional teaching and learning approach wherein they act as knowledge transmitters while students act as the dormant recipients of knowledge (RoK, 2012a).

In a fast changing and challenging world that requires skilled labour force, it is critical to adopt new models of teaching and learning that help learners to design, manage their own work, foster among them ability to communicate effectively, collaborate with others, research on new ideas, collect, synthesise, and analyse information in addition to developing new products and applying varied bodies of knowledge to novel problems that arise in the 21st century (Boix-Mansilla & Jackson, 2011; Darling-Hammond, cited in Saavedra & Opfer, 2012; P21, 2009). To promote these skills among learners IBL is imperative. Hence, Biology curricula around the world should emphasize the philosophy of inquiry in Science teaching, as teacher-centred methods like lecturing, note-taking and verification type laboratories (Yildrim, 2012) are inadequate in developing Biology literacy and skills. It is therefore necessary to de-emphasise approaches in teaching and learning which delimit the active participation of learners and their involvement in critical thinking and acquisition of relevant skills such as SPS. Consequently, it is becoming increasingly important to understand what outcomes students attain in inquiry environments (Saunders-Stewart, Gyles & Shore, 2012). This assertion provided a basis for conducting this study.

According to Nwosu and Okeke cited in Ongowo and Indoshi (2013) SPS are interpreted to be mental and physical abilities and competencies which serve as tools needed for the effective study of Science and technology as well as problem solving and for individual societal development. A demand of the 21st century learners of Science is to acquire and develop SPS (Chebii, 2011). It is therefore necessary to understand the interpretation of SPS in this century. Thus in the 21st century, SPS are viewed as cognitive and psychomotor skills employed in problem solving and discovery learning. These skills include: gathering of data, transformation, interpretation and communication (Akinbobola & Afolabi, 2010). Basing on this study, SPS were defined as the skills that are used by learners to help them acquire and understand biological knowledge. This study focused on the following SPS: observing, classifying, communicating, measuring, predicting, inferring, controlling variables, defining operationally, hypothesising, interpreting data, experimenting and creating models. The indispensability of the application of SPS in knowledge construction and generation of scientific knowledge for problem solving as observed by Ongowo and Indoshi (2013) and Ozgelen (2012) confirms the necessity of its implementation in Biology teaching and learning.

The desire for quality and effective delivery in Science teaching is necessary for scientific and technological development. The Republic of Kenya (RoK) (2007) identified quality education that is globally competitive as a pertinent element that will help her arrive at her destination of Vision 2030. The education reforms in Kenya therefore advocated for instructional approaches that actively involve learners and that will expose them to acquire the skills for industrialization. Hence, the GoK in the sessional paper number 14 of 2012 for the restructuring of the current curriculum took cognizance of the need to make the curriculum relevant to today's global and societal needs that are embraced with scientific and technological advancements. In the same vein, the Ministry of Education Science and Technology (MoEST) emphasised the development of a balanced education curriculum and pedagogies that foster inquiry, critical thinking, communication, manipulative skills and competencies aligned to delivering the aspirations of Vision 2030 (RoK, 2012a) . The Kenya Institute Education (KIE), currently known as the Kenya Institute of Curriculum Development (KICD) succeeded in the reorganization and rationalization of the current Biology curriculum with a strong recommendation for the use of student-centred learning approaches (KIE, 2002).

Gender inequality is a concern and remains a key challenge today. The realization of gender equality and empowerment of women and girls will make advancements across all goals and targets of the SDGs (UN, 2015). Women and girls must enjoy equal access and quality education as well as equal opportunities with men and boys for employment at all levels. Apart from teaching approaches, gender is also implicated in students' academic achievement in Biology. The current picture in Biology education depicts gender disparity in the performance of Kenya Certificate of Secondary Education (KCSE) in Biology (Appendix I). From the table in Appendix I, there is an observation that girls mean scores in Biology over the years is lower than that of the boys in KCSE. This could be an indicator of women and girls being denied opportunities to study disciplines that will help drive Kenya to achieve her objective of Vision 2030.

Concerted efforts are called for so as to close or reduce the gender gap on the performance in Biology in relation to gender equality. World leaders have decided to narrow the gender gap in education (UNDP, 2015) and this is shown by the marked improvement geared to closing the gap in the decade starting 2010. This is an indication that the impact of goals directed to gender parity are being realised both at international and national levels (ibid). As much as efforts are being directed to close the gender gap, gender disparities in education still exist in most developing nations (Eshetu, 2015). Further improvement on gender equality in education may be achieved through efficient mainstreaming of gender perspective by employing an instructional method that shall contribute to reducing the gender gap in performance. Based on these observations, this study sought to establish whether IBL as a pedagogical approach influences performance in Biology as relates to gender. The SDGs focus on provision of lifelong learning opportunities that will help learners acquire knowledge and skills that are required to exploit opportunities and participate fully in societal development (UN, 2015).

The goal of any Biology teacher should therefore be to promote and nurture the development of SPS. Further effort in Kenya to promote appropriate pedagogy among teachers was the establishment of in-service education training (INSET) by Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA). CEMASTEA developed SMASE-INSET that is aimed at improving Science and Mathematics teachers' pedagogical skills that in turn will foster the development of SPS in learners. Unfortunately, there has been no marked improvement in the three Science (Biology, Physics and Chemistry) subjects in the decade starting 2000, indicating that the impact of SMASE-INSET is yet to be realised at least at the national (KCSE) level in Kenya (RoK, 2012b).

Similar concerns have also been voiced by KNEC. Statistics from KNEC (2011-2016) indicate that candidates recorded low mean percentages in the KCSE Biology examination (Appendix A). Correspondingly, a report by RoK and UNESCO indicated the same observation (RoK, 2012b). A number of studies in Kenya (Ngesu *et al.*, 2014; Samikwo; 2013; Wabuke, 2012) have been done to find out why students' scores are low. Studies conducted have attempted to examine the causal factors of low performance in Biology subject. Wareng Sub-County Secondary School Pentagon Joint Examination (WSCSSPJE) panel (2015) also recorded similar remarks. Data on examination analysis on the WSCSSPJE from the Wareng sub-county education office report indicated that in the 2015 examination, secondary school students were unable to effectively answer questions that demanded the application of skills such as measuring, calculating, creating models, critical thinking and problem solving in Mathematics and Science (Biology, Physics and Chemistry) as was exhibited by the mass failure in these examinations (WSCSSPJE, 2015).

Considering the subject mean scores for the year 2014; Biology subject mean score for Form three was as follows: first term 2.968, second term 4.067 and third term 3.977 (Sub-County Education Office report SCEO-Wareng, 2015a). In term 1 2015, Biology subject mean score for Form three level was still low (3.248). The WSCSSPJE report further asserted that students generally lacked observation, communication, interpretation, analytical, prediction, drawing and mathematical skills. The KNEC report (2013a) indicated that candidates recorded a low mean percentage in the Biology KCSE examination (31.63) as shown in Appendix I. According to KNEC (2013), the low mean percentages were attributed to instruction that is based on mere transfer of factual information, lack of creativity, simple memorization of biological facts and failing to link to biological processes. This also implied that students lacked the ability to relate practical activities to scientific concepts taught.

Despite the dismal performance of students in Biology subject over these years (KNEC, 2011-2016), studies conducted did not examine how inquiry teaching approach could foster the acquisition of SPS among students and promote understanding of biological concepts and impact on achievement in Biology tests and examinations. It is against this background that the present study sought to establish the effect of IBL on SPS acquisition and achievement in Biology among Form three students of Wareng Sub-County of Uasin-Gishu County of Kenya.

1.3 Statement of the Problem

In a rapidly growing and challenging world today, the demand for pedagogical approaches which foster the acquisition of 21^{st} century competencies among students has become imperative. So far, studies have shown that the persistent use of traditional teaching methods do not promote science process skills such as critical thinking, creativity, communication and manipulative skills among students. Despite the poor performance of students in Biology at KCSE over the years, attempts through research to improve students' results have merely confirmed the critical need for teaching methods that will involve students' active participation and instill in them the skills that will also facilitate their achievement in Biology while making the teaching and learning of Biology meaningful in their daily lives. Though, inquiry has been shown to enhance investigative skills among learners, its implementation for the teaching of Biology in Kenya has been limited. In the same vein, facilitation of acquisition of skills through the application SPS in Biology has been uncommon. Hence, this study sought to investigate the extent to which IBL affects the acquisition of SPS among Form three students of Biology vis-a-vis improvement on their academic achievement in Wareng Sub-County in Uasin-Gishu County

1.4 Purpose of the Study

The purpose of this study was to establish the effect of IBL on the acquisition of SPS and its impact on students' achievement in Biology.

1.5 Objectives of the Study

The main objective of this study was to determine the extent to which inquiry-based instruction affects the acquisition of SPS and impacts on achievement among Form three Biology students in Wareng sub-county of Uasin-Gishu County, Kenya.

The specific objectives drawn from the main objective that guided this study were:

1. To determine the influence of IBL on students' level of acquisition of Science Process Skills in Biology.
2. To establish the difference between students achievement when taught using IBL approach and TL approach in Biology subject.
3. To examine the interaction effect between IBL and gender on students' achievement in Biology subject.

1.6 Research Questions

The following main research questions guided the study:

What is the effect of inquiry-based learning on acquisition of SPS and its impact on achievement among Form three Biology students in Wareng Sub-County, Kenya?

The following main research questions guided the study:

1. What is the mean score of students' acquisition of science process skills in Biology using inquiry based learning?
2. What is the difference between mean achievement score of students taught Biology using IBL and those taught using TL?
3. What is the interaction effect between IBL and gender on students' achievement of Science Process Skills in Biology subject?

1.7 Hypotheses of the Study

The following null hypotheses guided the study at $\alpha = .05$ level of significance.

Ho_1: There is no significant difference between mean achievement score of students when taught Biology using IBL and those taught using TL.

Ho_2: There is no significant interaction effect between IBL and gender on students' achievement in Biology subject.

1.8 Justification of the Study

Science Process Skills are among the skills that separate students who are prepared for increasingly complex life and work environments in the 21st century from those who are not (Saavedra & Opfer, 2012). Science Process Skills are useful in helping learners interact with their environment and seek ways of improving it. One of the objectives of teaching Biology subject at secondary school level is to impart skills that will make the learner equipped to exploit the resources in their environment without causing destruction (MoE, 2003). This goal is in consonance with the SDG on environment sustainability. Some of these skills are SPS; therefore the teacher should be abreast with the teaching method that will develop scientific skills among learners who can then apply them in their day-to-day life (Kazeni, 2005).

Based on the literature reviewed it is evident that the prevailing teaching methodology is a teacher-centred approach, even though it has been recommended that teachers use inquiry approaches to achieve Biology subject objectives and make learning student-centred (RoK, 2012b). Hence, the basis for conducting this study was to identify potential IBL outcomes in Wareng Sub-County that will help students acquire, demonstrate and master SPS. These skills are requisite for them to learn biological concepts hence perform well in Biology subject and apply biological knowledge in the real world especially towards the realisation of Vision 2030 and the SDGs.

1.9 Significance of the Study

The instructional approach selected by teachers during teaching and learning plays an important role in the construction of knowledge by students in the Biology classroom, hence the necessity of applying effective teaching and learning strategies. Concerned stakeholders in education do not have a clear direction of instructional strategies that are effective on the acquisition of Science Process Skills in the classroom and achievement in Biology. In an effort to improve the teaching and learning of Biology in Kenyan schools, the findings of this study will be useful to:

(i) The GoK, specifically MoEST (policy maker) and curriculum developers (KICD); it will provide information about IBL and how it can help to bridge the gap between pedagogy and learning outcomes such as acquisition of SPS and achievement in Biology;

(ii) Teachers of Biology, whereby it will help improve on their teaching practices thus improve delivery of content;

(iii) Students of Biology will be informed on how to improve their abilities to learn by allowing them to engage in deeper learning, also develop and apply SPS thus improve performance in Biology;

(iv) Findings of this study will add to the existing body of knowledge in Biology education and also form a basis for further research.

1.10 Assumptions of the Study

The study made the following assumptions:

(i) The instructional approach used (IBL) in this study allowed students' to acquire and master SPS in Biology.

(ii) The IBL approach used in this study was adequate to impart knowledge and help students' understanding of Biological concepts.

(iii) The learning outcome observed was due to the IBL approach used in this study.

(iv) The Biology Science Process Skill Achievement Test (BSPSAT) was a reliable tool to measure the achievement of SPS in Biology subject.

(v) The Biology Science Process Skills Questionnaire (BSPSQ) as a tool for data collection was based on self reporting by the participants; the study assumed that the participants did not withhold useful information, thus was adequate to measure the acquisition levels of SPS.

(vi) The performance of students in the BSPSAT that was used in the study was valid and reliable to determine the effectiveness of IBL.

(vii) The time allocated for the treatment period, between the pre-test and post-test was adequate to influence an effect on acquisition of SPS and achievement.

1.11 Scope of Study

The study was conducted in Wareng sub-county of Uasin-Gishu County in Kenya. The study focused on IBL instructional strategy, acquisition of SPS and achievement in Biology among Form three students. Form three students were selected because at form three level students are mature and can comfortably move through the phases of the 5E learning model compared to their juniors (form one and two). Also the topic of interest (ecology) is covered at Form three as per the Biology syllabus. Ecology topic was chosen because learners can interact with the environment through conducting practical activities, enhancing their ability to develop and apply SPS in a natural setting. Approaches to learning covered by IBL can employ small-scale investigations such as fieldwork which can be achieved in the ecology topic. Form four students would have been preferred, but they were not selected because of their busy schedule in preparation for their KCSE at the end of the year. The study focused on the secondary school Biology curriculum because secondary mixed day schools were exclusively used in this study. Teachers of Biology in the selected schools (experimental groups) were subjected to an induction for a period of three days and were regarded as trained research assistants. They assisted the researcher to conduct lessons using IBL approach.

1.12 Limitations of the Study

The study was limited by the following conditions:

i) The study employed a quasi-experimental design. This design advocates for non-random assignment of subjects. This implies that the results of this study are limited to the study population and as such, cannot be generalized on the entire population.

ii) The use of intact groups and the Solomon fourfold design led to a small study sample that was not representative of the study population.

1.13 Theoretical Framework

The theoretical framework of this study was based on the constructivist learning theory. This theory states that learning is an active process of creating meaning from different experiences (Brooks & Brooks, 1993). Constructivism as applied to learning is derived from the work of Piaget (1973) and Vygotsky (1978). Piaget advocated for individual constructivism and asserts that individuals construct their own understanding with little or no outside influence (cognitive constructivism). On the other hand, Vygotsky advocated for social constructivism and argues that social constructs such as the environment (human beings and objects) influence construction of knowledge.

The constructivist learning theory posits that learning occurs through experience and discovering the surrounding of the learner. According to constructivists, effective teaching must offer experiences that build on what students already know so that they can make connections to their existing knowledge structures; encourage students to become active self-directed learners; provide authentic learning opportunities; and involve students working together in small groups (Spronken- Smith, 2007). This theory supports IBL because students are encouraged to be actively involved in the learning process by relating their previous experiences with new information. The interaction between individuals and their physical environment enhances their ability to construct knowledge. Constructivism requires that learning be an active process where learners construct new concepts and ideas depending on their past or current knowledge (Chi, 2009).

Therefore the primary goal for constructivism is allowing students to make their own learning experiences through interacting with each other, thus enhancing knowledge and skill acquisition. This is different from traditional learning where the teacher uses direct instruction to transfer knowledge and skills. Moreover, students spend most of their time working individually (Miller, 2014). The application of this theory in this study allowed learners to construct knowledge through investigation. Inquiry-based learning together with 5E learning model, provided students with a wide range of learning experiences when learning Biology thus enhanced deeper conceptual understanding and skill development which promoted skill acquisition and achievement in Biology.

The learning model that guided this study was based on Bybee's 5E learning model. This 5E model has five key phases that allowed learners to go through processes of inquiry so as to engage in the learning process–the form of inquiry at this phase was mainly questioning, explore–learners constructed knowledge through carrying out activities, explain–learners constructed understanding of concepts through sharing of information, elaborate– this stage allowed for deeper understanding of the concept or skill in question and evaluate–it provided the teacher with the opportunity to assess the concept or skill learnt. Because processes of inquiry can be sequenced, IBL blends well with the 5E learning model. Learners are able to organise their learning experiences thus understanding of concepts is progressive (Spronken-Smith, 2007).

The 5E learning model allows for learning experiences to be in a series so that learners have the chance to construct their understanding of a concept during the teaching and learning process (Bybee, Taylor, Gardner, VanScotter, Powell, Westbrook & Landes, 2006). Students use their own understanding from within (individual constructivism) so as to influence what is around them (teaching and learning resources)–social constructivism at the same time they construct new knowledge or improve on the previous knowledge. The model leads students through five phases of learning that are denoted by the first letter of the activity that dominates each stage. The names of these activities begin with the letter E, that is: Engagement, Exploration, Explanation, Elaboration and Evaluation. Bybee's 5E learning model is represented in Figure 1.1.

The details of the stages of the 5E are expounded. In the *engagement* phase the teacher assesses the learners' prior knowledge and helps them become occupied in a new concept through the use of short activities that promote curiosity and elicit prior knowledge (Bybee *et al*., 2006). Students write and think about what they already know before beginning the lesson. The activity given to learners should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking towards the learning outcomes of current activities or lesson.

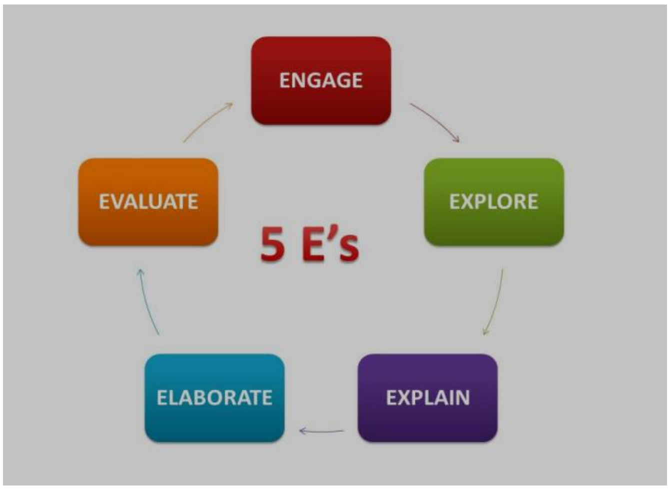


Figure 1. 1: Bybee's 5E learning model

Source: Journey in Technology (2011)

Exploration experiences provide students with a common base of activities in which current concepts (i.e. misconceptions), processes, and skills are indentified and conceptual change is facilitated. Learners may complete practical activities, that is; they may design and conduct a preliminary investigation where they make predictions about an experiment that will help them use prior knowledge to generate new ideas, explore complex questions and possibilities (Bybee *et al*., 2006).

The *explanation* phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviours. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the text book may guide them towards a deeper understanding, which is a critical part of this phase (Bybee *et al*., 2006). In the *elaboration* phase teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information and adequate skills. Students apply their understanding of the concept by conducting additional activities (Bybee *et al*., 2006).

The *evaluation* phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the lesson objectives. Evaluation is central in the model and takes place virtually in every phase of learning. This phase provides a summative assessment of what students know (Bybee, 2002). The application of this model in this study was based on determining the extent to which IBL affected Biology students' acquisition and achievement. The limitation of 5E learning model is that, it is time consuming (Ajaja, 2013) because of the five stages which may not be workable to achieving the immediate lesson objectives in a period of 40 to 80 minutes. This limitation was minimised by allocating various tasks to students so that they worked in groups.

1.14 Conceptual Framework

The conceptual framework of this study is represented diagrammatically in Figure 1.2. The relationships between the variables of the study are illustrated in the figure. Inquiry-based learning is the independent variable while TL is the control variable for the independent variable (IBL), IBL and TL are conceptualised as factors that influence students' acquisition of SPS and achievement in Biology (that is, the dependent variables). The extraneous variables may influence the independent and dependent variable by either the researcher not being aware of them or has no control over them.

The students' ability to acquire and master these skills during learning may be influenced by various factors such as teachers' training and their epistemological/ knowledge beliefs/ views on teaching and the time interval between pre-test and post-test. In addition, learner factors such as; socio-economic background, past experiences/ knowledge, beliefs, students' age, values and curiosities may influence the learning process. These factors (extraneous variables) need to be controlled so as to realise preferred learning outcomes. Teacher factors (epistemological/ knowledge beliefs/ views of teaching) were controlled by selecting teachers who were inducted on the 5E learning model. Student factors were mitigated by exposing learners of the experimental group to a teaching-learning environment that displays an IBL environment for a period of two weeks before commencement of the study. Students of the same class were involved in the study to minimise age differences. Gender was considered as a moderating variable and the interaction effect of IBL and gender was determined on the students' achievement in Biology. Students from mixed or coeducational schools were used in the study to minimise the differences of the learning environment for both boys and girls.

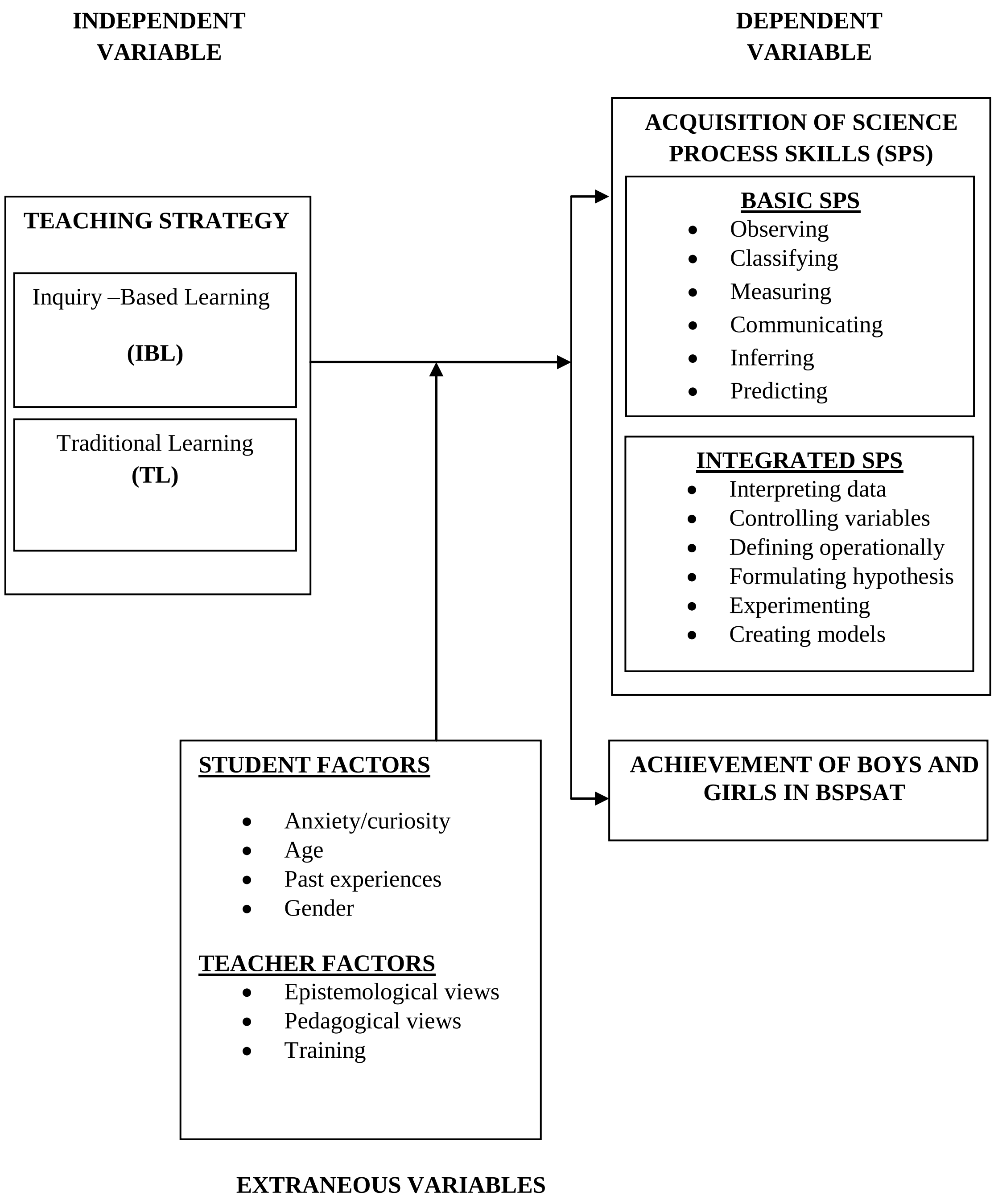


Figure 1. 2: Conceptual framework showing the relationship of variables for determining the effect of Inquiry-Based Learning on students' acquisition of SPS and achievement in Biology subject.

Source: Author, 2015

1.15 Summary of Chapter

This chapter introduced the study and outlined its background. This study observes that there exists a challenge in establishing which instructional approach shall equip students with the skills needed in the 21st century. To promote relevant skills among Biology students, studies have shown that inquiry based learning pre-eminently helps students rather than traditional teaching methods used by Kenya teachers. The statement of the problem gives an indication that the acquisition and achievement in Biology is impaired in the absence of learner-centred approaches to teaching. This is evidenced by the low mean percentages in the KCSE Biology examination. The purpose of this study was to identify a learning approach that ensures learners of Wareng sub county, Uasin- Gishu County, Kenya acquire and apply SPS in Biology subject. The objectives of the study have been covered as well as the research questions and hypotheses guiding the study. The study is justified because; an objective of teaching Biology subject is to impart skills such as SPS which are useful in daily life. Moreover the findings of the study will be helpful to concerned stakeholders. The assumptions of the study have been given in addition to the limitations, which arose from the choice of the design. The theory that guided the study was based on constructivist learning and the conceptual framework illustrating the study variables diagrammatically. The next chapter presents the reviewed literature.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of the Chapter

This chapter covers the literature review on themes that relate to the study variables. It outlines principles of inquiry-based learning (IBL), inquiry-based learning in Biology education, Science Process Skills (SPS), IBL and acquisition of SPS, IBL and achievement, Gender and achievement and then summary of the chapter.

2.2 General Literature Review

This literature covers general information on inquiry-based learning as an instructional approach.

2.2.1 Principles of Inquiry-Based Learning

Inquiry is an active learning process that stimulates students to experience the process of knowledge creation by developing challenging situations through observation and questioning phenomenon using explanation (Hattie, 2013; Spronken-Smith, 2010). Students are actively involved in the process because they design and conduct experiments, collect and analyse data, draw conclusions from data and formulate models (Hattie, 2013). According to Minner, Levy and Century (2010), inquiry as an instructional method involves three key activities. These are; what learners do, how they learn, and the pedagogical approach that teachers employ.

In Science, inquiry refers to the abilities students should develop to be able to design and conduct scientific investigations (NRC, 2000). Scientific inquiry is constituted by a set of activities characterized by problem-solving in which a newly encountered phenomenon becomes a challenge for thinking. Scientific inquiry can also be looked at as a set of activities that begins with a careful set of systematic observations, which then proceeds to designing measurements that are required. It is then followed by a clear distinction between what is observed and what is ideal under the circumstances (Gagne, 1963). In instruction; inquiry refers to the teaching and learning strategies that enable concepts to be mastered through investigation and practical work (NRC, 2000). Thus, inquiry is not an impartial process, but that which actively engages learners' by creating interest through challenges that allow them to connect their world to develop knowledge using reasoning and thinking skills (NRC, 1996; Nworgu & Otum, 2013).

Inquiry-based learning can range from more structured and guided activities, applicable at lower levels of education, through to independent research at advanced levels of teaching (Spronken-Smith *et al.*, 2011). Inquiry can be categorised into three categories as developed by Staver and Bay (1987). These categories include:

- Structured inquiry; which involves teachers presenting a problem and giving guidelines of how to tackle it,
- Guided inquiry; the teachers use questions to stimulate inquiry in the learners as the student self-direct themselves in terms of establishing answers to these questions, and
- Open inquiry; students formulate their own questions, go through all the stages of inquiry (i.e. problem identification, question formulation, identification of variables in question, experimentation, collection and analysis of data, synthesising and reporting of results).

Inquiry learning approach presents a number of benefits to the teaching and learning process. Some of which include: provision for more space for experimentation and observation where the students construct their own knowledge (OECD, 2006); creating realistic learning environment that fosters transfer of learning in out-of-class situations (Saunders-Stewart, Gyles & Shore, 2012); motivation of learners by engaging them in complex and personally relevant questions (Spronken-Smith, 2010); the increased engagement in the learning process may allow students to improve their understanding of concepts and skills.

In addition, in an inquiry-based approach, authenticity and relevant learning tasks provide the necessary context and engagement into which learning the elements or background information about a topic can be embedded in a more productive way (Stephenson, n.d); intellectual development is also achieved through questioning knowledge and development of critical thinking skills (Harlen & Allende, 2009); inquiry is also useful for achieving a variety of student learning outcomes related to academic achievement, knowledge retention, student attitudes, process skill acquisition, analytical skills, creativity and interaction between teachers and students (Spronken-Smith *et al*., 2011). When compared with traditional delivery models of teaching and learning that focus only on pre-existing knowledge or skills, Stephenson established that inquiry remains open to the unknown, that which has yet to be discovered. This study sought to establish some of the benefits and learning outcomes that were related to inquiry in Biology subject.

2.3 Related Literature Review

This literature covers information on inquiry-based learning as an instructional approach in Biology Education.

2.3.1 Inquiry-Based Learning in Biology Education

Inquiry-based learning supports students' understanding of Biology by providing them with opportunities to independently investigate through both research and experimentation (Cruz, 2015). Learning through inquiry has long been a goal of Biology education, with its importance articulated as early as 1910 by John Dewey (Alberta Education, 2007). In a meta-analysis by Horner (2011), preference is given to inquiry as a more fundamental teaching methodology in Biology than other pedagogies or classroom activities.

Inquiry-Based Learning as a teaching-learning method is essential to the development of biological ideas and for understanding the world. The impact of inquiry as a teaching method in Biology education is therefore useful for both scientific and technological development. A study conducted by Ajaja (2013) involving senior secondary class II (SS II) students, from public secondary schools in the Delta State area in Nigeria, on the effects of 5E learning cycle on students' achievement in Biology, found out that the use of 5E learning cycle led to enhanced achievement in the 5E learning cycle group than those taught with the regular lecture method. Another study conducted by Simsek and Kabapinar (2010), on the effects of inquiry-based learning on students' conceptual understanding of matter, Science Process Skills and scientific attitudes among fifth grade science students in Turkey established that IBL is a method that fosters the acquisition of skills among students. Furthermore, they noted that when engaging in inquiry learners pose questions, search for explanations, test these explanations and produce knowledge. These activities require the use of SPS.

Studies conducted in Biology subject show that IBL enhances learner participation during Biology lessons (Khan & Iqbal, 2011; Opara, 2011; Wambugu & Changeiywo, 2008). On the contrary, a study by Branton (2012) on comparing Biology honours and Biology academic students observed that IBL did not seem to make a difference over the traditional learning style in the academic group. This may indicate that benefits of IBL at advanced levels such as tertiary may not be realised because students may be capable of organizing the ability to learn irrespective of the instructional strategy employed. However, Franklin (n.d) asserts that IBL encourages the use of students' derived investigations, hence knowledge is more relevant and meaningful rather than facts acquired through passive transmission from a teacher.

Moreover, Chu *et al*., (2012) place a cautionary claim that if IBL is implemented in an inappropriate manner, it is possible that this would significantly hinder students from effective participation and learning and therefore, this may be a waste of learning time. A further assertion by Hattie (2013) indicates that when teachers consider inquiry in a particular topic it is important to consider how students might participate in the learning process. Emphasis should be placed on what is already known (the foundational concepts or key-ideas) while allowing for space for the unknown where students can create or design experiments, collect and interpret data so as to construct new knowledge.

Several studies have been done to compare IBL and TL in Biology (Abdi, 2014; Branton, 2012; Hughes & Ellefson, 2013; Ikitde, 2013; Khan & Iqbal, 2011; Opara, 2011). Findings from these studies indicated the effectiveness of IBL over TL. At different levels of learning, inquiry has offered benefits that are valuable. Research conducted by Asiango (2010), on the effect of inquiry-based instruction on Pre-

School children's achievement in Science in Dagoretti division, Nairobi, Kenya revealed that children taught using inquiry-based instruction performed better in Science than those instructed using TL. This observation may be attributed to the pre-school children being exposed to processes of inquiry that help them to create knowledge sequentially and develop the knowledge to higher levels allowing learners to experience a deeper sense of learning.

At secondary school level, Ongowo (2013) conducted a study in Gem Sub-County in Kenya on secondary school teachers' perceptions of a Biology constructivist learning environment. The study indicated that in a constructivist environment for learning Biology such as one encompassed by IBL, teachers perceived student negotiations (activities) as the most preferred learning environment in Biology classrooms as it provided students with opportunities to explain and justify to other students their newly developed ideas–students become the centre of the learning process. The study also indicated that teachers related Biology learning to what happens out of the school—value beyond the classroom. Hence learning became more meaningful. These findings are similar to those reported in literature by OECD (2009).

Another study by Khan and Iqbal (2011) on the effectiveness of inquiry-based teaching approach on the development of scientific processes and skills among ninth grade secondary school Biology students in Pakistan showed that an inquiry-based teaching laboratory approach had a positive learning outcome on the students. The mean gains of the students taught by inquiry-based teaching laboratory approach were significantly higher than those students taught by traditional laboratory method. The results also indicated that the mean difference between the inquiry-based teaching laboratory approach group and the traditional laboratory teaching group were statistically significant in favour of the students exposed to inquiry-based teaching laboratory approach.

On the other hand, substantial studies on the effect of cooperative learning (an instructional strategy that is student-centred) in the learning of Biology at secondary school have been conducted and their findings have shown its effectiveness on learning outcomes such as achievement, self-concept, motivation and interest (Achor & Wude, 2014; Ajaja, 2013; Bukunola & Idowu, 2012; Muraya & Kimamo, 2011; Orara, Keraro & Wachanga, 2014). However, the effectiveness of IBL in acquisition of SPS in Biology is understudied; empirical evidence was limited to studies outside Kenya. Studies in Kenya focused on Physics and Chemistry subject. Thus, the need to investigate the extent to which IBL affects learning of SPS in Biology in secondary schools.

2.4 Science Process Skills

Science Process Skills can be defined as the cognitive ability of creating meaning and structure from new information and experience (Cruz, 2015). Science Process Skills are also viewed as activities that students carry out in scientific investigations and or learning to enable them acquire scientific knowledge and skills (Abungu, Okere & Wachanga, 2014). Science Process Skills are important in Biology in view of the fact that they contribute to understanding of abstract concepts in Biology, which would remain hidden if taught theoretically (Hodson, 1990). The importance of SPS is basically to allow students to describe objects and events, ask questions, construct explanations, objects and or models, test those explanations against current scientific knowledge and communicate their ideas to others (Opara, 2011).

Science Process Skills enable students to experience hands-on engagement with science materials when solving problems using practical approaches. Therefore application of SPS allows students to investigate important issues in the world around them (Ongowo & Indoshi, 2013). The emphasis of process-based activities in science lessons cannot be doubted, as this is clearly evident in the objectives and instructional programmes in science subjects at the secondary school level (Abungu *et al.*, 2014). This therefore calls for learner–centred instructional methods that allow learners to participate in the learning process (Köksal, 2008; Timur & Kıncal, cited in Yildrim, 2012). SPS are categorized into two groups, basic and integrated Science Process Skills.

2.4.1 Basic Science Process Skills

Basic Science Process Skills (BSPS) are referred to as the simpler process skills that provide a foundation for learning more complex (integrated) skills (Espinosa, Monterola & Punzalan, 2013). These skills include observing, deducing (inferring), measuring, communicating, classifying and predicting (Padilla, 1990). Basic SPS provide an intellectual groundwork in scientific inquiry such as the ability to organize and describe natural objects and events (Brotherton & Preece, 1995; Sevilay 2011). According to Sevilay (2011) SPS help students to develop a sense of responsibility in their own learning, increase permanency of learning as well as teach them research methods. Furthermore Opateye (2012) notes that SPS are helpful in the development of favourable scientific attitudes and disposition in learners. These include curiosity, imagination and enthusiasm for inquiry. This study focused on the six BSPS which are used in Biology subject. These BSPS include:

2.4.1.1 Observing

Observing is the ability to perceive the natural world through the five senses and to gather information about objects or events (Achor & Shikaan, 2015; Cruz, 2015). The process skill of observation is also defined as using of one's senses to perceive objects and events; their properties and behaviour or their characteristics (Abungu *et al.*, 2014; Ongowo & Indoshi, 2013). Learners are required to be keen on features of objects or events when observing them. An observation involves the description of phenomena, for example during a field study of organisms in their habitats, students would be required to observe the organisms in a particular habitat and state how they relate with each other. Observation skill brings on board other BSPS such as classifying, measuring, inferring, communicating and predicting.

In Biology lessons, students should be taught on how to conduct correct observations by taking note of the features that describe the object in question through the stages of inquiry and 5E learning model. The ability of learners to use their senses to observe things critically is vital for learning Biology. The Biology syllabus emphasises the acquisition and development of observation skill for effective learning in Biology and to help learners in their day-to-day life (MoE, 2003). Tasks that call for application of the observation skill have presented inadequacies in terms of performance (KNEC, 2011-2016). It is therefore necessary to establish whether IBL as a teaching-learning approach facilitates the acquisition and development of the observation skill in Biology and then measure learners' output in terms of achievement.

2.4.1.2 Classifying

Classifying is the act of grouping or ordering objects or events into categories based on properties or criteria (Achor & Shikaan, 2015; Cruz, 2015). Learners can be able to properly perform an activity on classification if they have a high level of acquisition of the observation skill (Achor & Shikaan, 2015), which helps them to recognise features of living organisms in terms of similarities and differences during Biology lessons. Classification as a SPS is important because it contributes to the extent to which students understand, conceptualise and attach meaning to scientific ideas. Classification keys are useful for conceptual organisation in the sense that they facilitate students' understanding of conceptual scheme and students' ability to retrieve information from a conceptual scheme (Ango, 2002).

2.4.1.3 Measuring

In Chiappetta and Koballa's study cited in Zeidan and Jayosi (2015), measuring as a science process skill refers to the ability to express the amount of an object or substance in quantitative terms while Cruz (2015) considers it as the ability to use both standard and non-standard measures and estimates to describe the dimensions of an object or event. The learning process is facilitated by learners being provided with feedback about their answers to problems, when learners are able to receive feedback they can be able to correct their mistakes (Ango, 2002). A major way by which students receive feedback from the investigations they conduct is through measurement. Measurement skill provides students with an opportunity to appraise themselves (Ango, 2002). Measurement skill is developed when students are able to use measuring instruments appropriately to give dimensions of objects in the required units. During Biology lessons students use various instruments such as microscopes and thermometers to establish required measurements. The objective of including tasks that involve measurements in the secondary Biology syllabus is to allow students to acquire and develop the measurement process skill.

2.4.1.4 Communicating

Communication skill refers to the ability to use words and graphic symbols to transmit, describe an action and object or event (Cruz, 2015; Ongowo & Indoshi, 2013). Communication is an important aspect in scientific investigation. Communication skill must be inculcated in the early stages of teaching and learning of science so that it is effectively applied. Learners should be able to express their thoughts, ideas and research findings (Ango, 2002) to their peers during the phases of the 5E learning cycle through discussions. Communication skill can also be strengthened through speech, writing reports, diagrams or drawings, graphs, charts, tables, figures and mathematical formulae (Achor & Shikaan, 2015).

2.4.1.5 Inferring

In the study of Chiappetta and Koballa, inferring as a science process skill is the ability to make explanations of observations, objects, data or substances in quantitative terms (as cited in Zeidan & Jayosi, 2015). Inferring could also refer to the ability to interpret observations based on prior experiences or perceptions that is, making assumptions using observations made (Achor & Shikaan, 2015). An inference can also be termed as making an “educated guess” about an object or event based on previously gathered data or information. Inference skill allows learners to connect previous knowledge with new knowledge since students require theoretical knowledge to apply it in an experiment that they are conducting. Inquiry-Based Learning allows for oscillation between prior and new knowledge with ease thus learners are able to draw conclusions.

2.4.1.6 Predicting

Predicting refers to stating the outcome of a future event based on the pattern of evidence by extension of data or using past observation in Chiappetta and Koballa's work cited in Zeidan and Jayosi (2015). Stating the outcome of a future event can be viewed as an intelligent guess of what would happen in the future by using scientific knowledge (Yadav & Mishra, 2013). Prediction skill is based on other Science Process Skills such as observation, measurement and inferences about observed events. Learners can therefore establish patterns of events, for example, life cycle of plants and predict the seasons they are likely to flower and disperse their seeds.

2.4.2 Integrated Science Process Skills

Integrated Science Process Skills (ISPS); also referred to as the immediate skills used in problem solving or conducting Scientific experiments (Rambuda & Fraser, 2004). The integrated skills include controlling variables, defining operations, formulating hypotheses, interpreting data, experimenting, and formulating models (ibid). The integrated SPS are the terminal skills for solving problems or doing science experiments and the ability to carry out ISPS is attributed to hypothetical-deductive reasoning as affirmed by Sevilay (2011). This study focused on six ISPS which are used in Biology subject. These skills include:

2.4.2.1 Interpreting Data

Interpreting data as a science process skill refers to the organisation of data and drawing conclusions from it (Cruz, 2015) so as to make meaning out of the gathered data or information. The secondary Biology syllabus provides for experiments or investigations (project work) from which data can be collected, analysed and interpreted. Critical observations of investigations are vital to ensure appropriate and correct data is collected. Interpreting data makes it possible for the observations made to have meaning (Abungu *et al.,* 2014) to the beneficiaries of the findings. After data has been interpreted, inferences can be made to produce and extend knowledge which may have an importance or meaning when studying a concept in Biology subject.

2.4.2.2 Controlling Variables

Controlling variables is the ability to identify variables that can affect an experimental outcome. This involves keeping most variables constant while manipulating the independent variable or properties that relate to situations or events for the purpose of determining causation (Cruz, 2015; Ongowo & Indoshi, 2013). Testing of variables requires careful analysis of the problem in question so as to be able to identify the independent and dependent variables then control one variable at a time to determine the effect it has on the experimental setup. For example, when assessing plant growth in different habitats, learners will be required to identify the requirements for plant growth (variables) such as fertilizer quantities, light intensity, temperature and water to mention a few, and determine their effect on the plant. Data collected by learners will be interpreted; interpretation may be correct or incorrect. It is therefore important for learners to present their findings so that misconceptions are corrected. Observations and interpretation of data is dependent on theoretical knowledge in Biology.

2.4.2.3 Defining Operationally

Defining operationally as a science process skill is described as to the ability to state how to measure a variable in an experiment (Cruz, 2015; Ongowo & Indoshi, 2013).

Learners should be able to explain how to measure given factors in an investigation, for example, determining the rate of transpiration on plants that grow in different environmental conditions. Students should be able to account for the procedure of how the said variable will be measured. The inquiry-based learning approach allows students to understand experiments in Biology by operationally defining variables in the context of their investigation (Cruz, 2015). Therefore conducting investigations in natural settings helps learners understanding Biology in the real world (Achor & Shikaan, 2015).

2.4.2.4 Hypothesising

Formulation of hypotheses refers to stating the expected outcomes of an experiment or investigation (Cruz, 2015; Ongowo & Indoshi, 2013) while Chiappetta and Koballa’s study cited in Zeidan and Jayosi (2015), define hypothesising as the ability to state tentative generalisations of observations or inferences that may be used to explain a relatively larger number of events subject to immediate or eventual testing by one or more experiments. Learners may provide some plausible explanation for the observations made using tentative testable statements. When learners attempt to explain given observations that are consistent to evidence provided and can be tested, then they are formulating hypotheses. Students should be able to find new information about objects or events by examining information that is already established, learners can then clarify their perceptions about the information by making an ‘educated guess’ about a problem that is, formulate a hypothesis (Achor & Shikaan, 2015).

2.4.2.5 Experimenting

Experimenting process skill involves testing hypotheses through the manipulation and control of the independent variable and observing the effects on the dependent variable (Achor & Shikaan, 2015). It also implies being able to conduct an experiment, including asking an appropriate question, stating a hypothesis, identifying and controlling variables, operationally defining those variables, designing and conducting experiments and interpreting results of the experiment (Cruz, 2015). Experiments involve problems whose solutions are unknown (Achor & Shikaan, 2015) and therefore require investigations that will establish solutions to these problems. Proper experimentation involves testing of hypotheses and if possible using control experiments to compare the outcome of the experimental and control setup. This will help determine the effect of the manipulated variable. Experiments can also be conducted during Biology lessons to establish results that can be used to make inferences. Experimentation skill enables learners to develop the ability to solve problems; if students are able to conduct experiments then they will be able to understand concepts related to topics taught and how they relate to the experiment.

2.4.2.6 Creating Models

Creating models refers to formulating a mental or physical model of a process or event (Cruz, 2015; Ongowo & Indoshi, 2013). The ability to create models helps students to make sense out of a pile of information. Therefore models are useful when presenting quantitative data and are also an important means of communicating scientific data (Yadav & Mishra, 2013). Models simplify the conceptualisation of information that is otherwise abstract by presenting it in a concise or summarised manner. Inquiry–Based Learning allows learners to express ideas and information confidently and creatively in a variety of modes of communication. This process skill also allows learners to collaborate with other learners, thus enhances the understanding of the problem in question, enabling them to produce outstanding results (Cruz, 2015). It is important to note that the basic and integrated SPS must be incorporated; learners are expected to be able to combine basic SPS for greater expertise and flexibility to design the tools they apply when they study or investigate phenomena (Ongowo & Indoshi, 2013).

2.5 Inquiry-Based Learning and Acquisition of Science Process Skills

The teaching of Science Process Skills is one of the most important aims of teaching Science Bybee & Deboer's work (as cited in Aydogdu, 2015) since acquisition of SPS enables students to gain skills that are necessary in solving everyday problems (Kazeni, 2005). The approaches used in teaching SPS have been identified as one of the factors contributing to acquisition of SPS and Science literacy, among other factors (Curtin University, 2014; Friesen & Scott, 2013; P21, 2010; RoK, 2009; RoK, 2012b). The integration of scientific knowledge and SPS can be fulfilled through IBL (Nuangchalerm, 2014). According to Nuangchalerm learning should be a process that stimulates behavioural change through skill acquisition and development; not just a process of transmission of knowledge. Inquiry as a method of teaching also relies heavily on the effective use of SPS by students to complete an investigation (Colley, 2006; Simsek & Kabapinar, 2010). Scientific inquiry exercises typically serve as the primary source of SPS development with inquiry being used to teach these skills (Wilke & Straits, 2005). An inquiry-based teaching and learning approach is therefore intended to help learners in acquisition of SPS (Stephenson, n.d). Science and technology literacy consists of developing SPS in individuals and making them lifelong learners (Yildirim, 2012).

Research findings indicate that IBL can be useful in enhancing the learning of Biology (Khan & Iqbal, 2011) as well as the development of Science literacy and scientific skills (Mutisya, Rotich & Rotich, 2013). Similar observations have been made in other subjects such as Chemistry (Abungu *et al.*, 2014) and Science (Simsek & Kabapinar, 2010). A study done by Mutisya, Rotich and Rotich (2013), in Narok West Sub-County, Kenya on assessing the conceptual understanding of SPS for inquiry teaching of primary school Science noted that basic SPS are acquired by learners when taught using IBL. In the study conducted by Khan and Iqbal (2011), they established that the *t*-values of various components of Science Process Skills were as follows: observing (3.730); classifying (6.979); measuring (5.771) and communicating (5.106). The significant results regarding the studied Science Process Skills showed that these skills can be developed in students at secondary school level through inquiry-based teaching laboratory method as well as traditional laboratory method, but inquiry-based teaching laboratory method was more effective.

Considering another approach of IBL, another study conducted by Nwagbo and Chukelu (2011) among senior secondary 1 (SS 1) students in Abuja, Nigeria on the effects of biological practical activities method on students' Science Process Skills acquisition, established that practical method was more effective in fostering students acquisition of SPS than lecture method. On the basis of field activities, Achor and Shikaan (2015) conducted a study among fifth grade students in Makurdi, Benue state of Nigeria to determine the effects of field-based inquiry method of instruction on level of SPS acquisition by students and established that students exposed to field-based inquiry method had significantly higher levels of SPS acquisition than those exposed to conventional method.

Science Process Skills are very important for the assessment of practical Biology. Some studies have examined into the extent of assessment of SPS in Biology examinations. In line with this view, Gacheri and Ndege (2014) investigated the extent to which practical SPS are assessed in Biology subject in Maara Sub-County of Kenya. Form three Biology students were assessed on their ability to apply SPS (manipulating, observing and drawing, reporting, interpreting, measuring and experimenting) in practical Biology. A document analysis of Biology paper three (practical paper) from 2006-2010 was done, the findings from the study revealed that most teachers in Maara Sub-County do not adequately test students for SPS in Biology practical examinations since students are rarely given practical tests. The KCSE Biology practical examination analysis also showed that SPS such as drawing and measuring are not adequately tested. Another study conducted by Ongowo and Indoshi (2013) investigated the level of testing of the SPS and identified the SPS inherent in KCSE Biology practical examination through document analysis over a period of ten years (2002-2012). They also classified the SPS that they identified into their respective categories. Findings from this research indicated that basic SPS had a higher percentage (73.73%) compared to the integrated SPS (26.27%) on the level of testing in the Biology KCSE practical examination.

In another study conducted by Yager and Akçay (2010), reports indicate that inquiry can help students understand concepts and apply SPS appropriately. This is supported by Hasan (2012), who argues that scientific inquiry is a point of convergence of all SPS and Science literacy as the teaching of Biology SPS is based on inquiry Pratt and

Hackett, cited in Ergul, *et al.* (2011). Inquiry–Based Learning has been widely used to increase literacy and skill development (Brickman, Gormally, Armstrong & Haller, 2009; Maundu, Sambili & Muthwii, 2005; Ongowo & Indoshi, 2013). Several researchers have advocated for the implicit and explicit impartation of SPS to the students so as to meet the present-day need of producing 'scientifically literate citizens' (Larson-Miller, 2011; NRC, 1996; Nuangchalerm, 2011).

Inquiry in Biology involves teaching Biology by having students engage in more Biology activities and exercises that encourage them to learn Biology (Olson & Louks-Horsley, 2000). Not only do students engage in simple inquiry, but also in processes such as observing, comparing, contrasting and hypothesising (Cuevas, Lee, Hart & Deaktor, 2005). Another observation made by Simsek and Kabapinar (2010) is that prior to the teaching intervention of IBL, the mean of the students' scientific process skills score was 13.50 which increased to 17.00 after the teaching intervention. However, the greatest improvements were detected especially in the students' measurement skills, correlation or classification skills and forming hypotheses. The pre and post-test scores for these sub-process skills were increased from 23 to 35, 27 to 40 and 13 to 30 respectively.

Studies conducted by Nworgu and Otum (2013) on the use of guided-inquiry with analogy on acquisition of SPS in Biology among junior secondary III students in the 'chemicals of life-food tests' sub-topic in nutrition indicated that in the pre-test, the mean achievement score of students under experimental condition was 51.53 with standard deviation of 8.42 while those students under the control condition had a mean score of 48.58 and standard deviation of 5.57. These results showed that the two groups were almost homogenous prior to the treatment intervention. After the treatment intervention, students exposed to the inquiry approach with analogy (experimental group) had a mean achievement score of 76.30 with a standard deviation of 9.60 whereas those under the control group had a mean achievement score 58.67 with a standard deviation of 8.56. These results suggested the experimental group performed better than the control group. In effect, the use of guided-inquiry complimented with analogy proved superior to a conventional instructional approach in enhancing students' acquisition of SPS. Analysis of data by Koksal and Berbseroglu (2014) on the effect of guided-inquiry on students' SPS, using repeated analysis of variance (ANOVA) indicated there is a significant effect of the treatment on the SPS of the students' Biology test scores. Furthermore, the results of the univariate tests indicated that there were significant interactions between the treatment, pre and post test scores for SPS measure. These significant interactions point out that guided-inquiry instruction is an effective teaching method to enhance positive learning outcomes among learners.

2.6 Inquiry-Based Learning and Academic Achievement

The teaching approach used by a teacher may affect students' achievement (Wambugu & Changeiywo, 2008), hence use of an appropriate teaching method is important to the success of the teaching and learning process. There are established findings on the scientific value of inquiry, particularly in developed countries. Open inquiry was found to be strongly associated with the sense of independence, ownership and achievement amongst learners (Hepworth & Walton, 2009; Levy & Petrulis, 2012). Through IBL students have been found to be more engaged in their work and eager to investigate the truth; eventually developing their inquiry tasks along with personal interests (Levy & Petrulis, 2012).

Inquiry-Based Learning has also been shown to result in better performance of students in terms of their research skills, subject knowledge and writing abilities (Chu, 2009). A great deal of research has shown IBL promotes achievement (Branton, 2012; Hughes & Ellefson, 2013; Khan & Iqbal, 2011; Opara, 2011). Findings of several studies have also shown that IBL is more effective in facilitating positive learning outcomes such as deep thinking and an ability to apply knowledge and reasoning skills when compared to TL (Chu *et al.*, 2012). A study conducted on effect of science process skill teaching approach on secondary school students' achievement in Chemistry showed that the science process skill teaching approach had a significant effect on students' achievement in the subject (Abungu *et al.*, 2014). Analysis of data by Koksal and Berberoglu (2014) on the effect of guided inquiry on students' achievement, using repeated analysis of variance (ANOVA) indicated there is a significant effect of the treatment on the achievement of the students' Biology test scores. Furthermore, the results of the univariate tests indicated that there were significant interactions between the treatment, pre and post test scores for achievement measure. These significant interactions point out the effective treatment of guided-inquiry instruction.

On the contrary, Branton (2012) in her study on the effects of teaching style on students' learning of DNA (Deoxyribose Nucleic Acid) observed that while comparing the academic students alone, IBL did not seem to make a difference on the students' performance over traditional learning style. According to Kirschner, Sweller and Clark (2006), in their article *why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, project-based, experiential and IBL* also note that evidence developed over the past-half century supports the view that minimally-guided learning does not enhance student achievement.

Previous studies focusing on the relationship between IBL and students' academic achievement in Biology (; Branton, 2012; Hughes & Ellefson, 2013; Opara, 2011) and Ecology (Achor & Amadu, 2015) have revealed that IBL indicated significant increase in academic achievement of students. The motivational benefit of using IBL to improve academic achievement is also illustrated (Njoroge, Changeiywo & Ndirangu, 2014; Vanosdall, Klentschy, Hedges & Weisbaum, 2007). Higher achievement is linked to more student engagement in the learning process as IBL provides for greater student engagement when learning (Branton, 2012).

A number of studies have been conducted at various educational levels; pre-school level (Asiango, 2010), secondary school level (Abungu *et al.*, 2014; Ongowo, 2013; Gacheri & Ndege, 2014) and college and university level (Branton, 2012; Hughes & Ellefson, 2013; Kwon, Rasmussen & Allen 2005; Rasmussen, Kwon, Allen, Marrongelle & Burtch, 2006). These studies indicate similar findings that IBL enhances achievement regardless of the education level. On the other hand, Hughes and Ellefson (2013) recorded in their findings that guided-inquiry methods yielded gains in academic performance on Graduate Teaching Assistants (GTAs). They concluded that providing GTAs with theoretical understanding of guided inquiry methods increased their quality of teaching in an introductory Biology laboratory course, thus improving teaching.

2.7 Gender and Academic Achievement

Gender refers to the socially constructed roles, behaviours, activities, and attributes that a given society consider appropriate for men and women (WHO, 2011). The issue of gender and gender stereotyping permeate every aspect of human endeavour (Nwagbo & Chukelu, 2011) therefore, it is equally important in education. Gender acknowledges the importance of cultural beliefs, socialisation and other influences on how individuals experience being male or female (Karuti, 2013). Gender is among the determinant factors that affect students' academic achievement. Gender related findings from studies on performance are able to provide indicators of how a national education policy is working with reference to equity when compared with other policies (EACEA, 2010). Generally, gender perspectives in education help to examine the action, decision making and learning outcomes and how they affect both male and female students (Katuri, 2013).

The nature of gender inequalities in education has changed greatly over recent years especially with regard to attainment (EACEA, 2010). In Europe, the most pronounced gender difference in achievement is the advantage of girls in reading over the boys, but in science achievement the gender difference is small. Despite science performance almost being at par, girls tend to have weaker self-concept in science than boys (ibid). The EACEA report that this could be as a result of students' interactions in schools that contribute to their social behaviour and eventually influence their socialisation into restricted gender roles. In Africa, similar trends reading are observed, (Eshetu, 2015). In Kenya, gender differences in science achievement are large (KNEC, 2011-2016); this contradicts the observation made in Europe. Gender parity in the performance of science subjects in KCSE is still wanting. Socialisation in education enables individuals acquire societal skills that can conform to a set of societal norms considered appropriate for males and females (Karuti, 2013). To some extent gender socialisation places males and female students in circumstances that disadvantage their academic achievement leading to gender inequalities in education. Gender differences in education can negatively affect economic, political and social platforms of any country (UNDP, 2015). The girls have lagged behind in the achievement of Biology; this is clearly illustrated in the KCSE Biology examination performance (KNEC, 2011-2016). The low performance is a contributing factor of the low representation of females in science-oriented fields.

Efforts are being made to encompass gender and gender equality as an interdisciplinary theme in school curricula (EACEA, 2010). The EACEA report observes that development and identification of adequate gender-specific teaching methods and guidelines is still lacking yet these contribute in counteracting gender stereotypes among learners. Gender in this study was a moderating variable. The concern of gender in learning spans over a number of issues such as attitudes, instructional methods, mental ability and achievement (Ayotola & Abiodun, 2010). This study focused on IBL, the interaction effect of IBL and gender on students' achievement was examined.

Several studies have been conducted on gender and achievement, Mubichakani (2012) conducted a study on the effect of computer based learning (CBL) in Mathematics in Bungoma, County of Kenya, and noted that there was no difference in achievement between the mean scores of male and female students in Mathematics when instructed using CBL. Computer based learning has also presented positive learning outcomes in Biology, studies conducted in Nigeria (Ayotola & Abiodun, 2010; Olakekan & Oludipe, 2016), have demonstrated similar findings as those of Mubichakani.

Various instructional approaches have been investigated and their effects on students' achievement determined. In Biology, various teaching methods have been investigated to determine their effect on learning outcomes. Studies conducted by Amedu (2015) on effect of jigsaw method on achievement in Nigeria concluded that teaching method was effective to enhance achievement in Biology. Boys achieved significantly higher than the girls when taught with jigsaw method. A study carried out in Ethiopia (Eshetu, 2015) on gender differences in achievement established that there was a difference between male and female students. The scores of the male students were higher than those of the females.

Studies have been conducted to examine the interaction effect of teaching method and gender on students' achievement. A study conducted on determining the interaction effect of school outdoor activity teaching method and gender on students' achievement found out that there was no interaction effect between school outdoor activities and students' gender on achievement in ecology topic (Achor & Amadu, 2015), a study was conducted by Nwagbo and Chukelu, (2011) also established similar results. Other teaching methods that yielded similar findings are peer tutoring approach (Ezenwosu & Nworgu, 2013), experiential learning (Okali & Okechukwu, 2014), and cooperative learning (Nneka, 2015). These studies have shown that there is no interaction effect between teaching method used and gender on students' academic achievement. These studies were conducted in other parts of the world, literature on studies conducted in Kenya were scarce. This study sought to specifically examine if there is any interaction effect between IBL and gender on students' achievement in Biology.

2.8 Critique of Literature Review

Based on the studies reviewed, there is an indication that the prevailing teaching method is a conventional approach that focuses on passive transmission of facts from the teacher to the learners (RoK, 2012a). This prevailing method has not yielded positive learning outcomes. So far, studies that have been conducted on the effect of IBL on achievement are: Asiango (2010) among pre-school children in Dagoretii, Nairobi, Njoroge *et al.* (2014) among Form two secondary school Physics students in Nyeri County and Abungu *et al.* (2014) among Form three secondary school Chemistry students in Nyando Sub-County. These studies examined the effect of IBL on achievement of knowledge, motivation and attitudes of students in different Sub-Counties this present study sought to establish the impact of IBL on SPS acquisition and how these skills are applied in the process of understanding biological concepts hence affecting achievement in Biology subject in Wareng Sub-County of Uasin-Gishu County, Kenya.

Concerning SPS acquisition: Khan and Iqbal (2011) examined ninth grade Biology students in Pakistan; Nwagbo and Chukelu (2011), Nworgu and Otum (2013) examined senior secondary students in Nigeria and also Achor and Shikaan (2015) among fifth grade science pupils in Nigeria. These studies were conducted outside Kenya. Related studies in Biology subject were limited hence the need to conduct this present study was inevitable. Considering SPS assessment, studies have been conducted by Gacheri and Ndege (2014) on students' practical SPS assessment in KCSE Biology practical examination and Ongowo and Indoshi (2013) on the level of setting SPS in KCSE Biology practical examination. These studies focused on practical assessment and not as such academic achievement of students in Biology subject. The present study sought to examine how IBL affects students SPS in terms of acquisition and application in understanding biological concepts in theoretical perspective and how this would affect achievement in Biology.

Another study that was conducted by Mutisya, Rotich and Rotich (2013) focused on the conceptual understanding of basic SPS using inquiry teaching among primary school teachers. This current study sought to examine the acquisition of both basic and integrated SPS among Form three students of Biology by learning through inquiry. More literature was available on other instructional strategies such as cooperative learning and how it affects achievement in Biology at secondary school level (Achor & Wude, 2014; Ajaja, 2013; Bukunola & Idowu, 2012; Muraya & Kimamo, 2011; Orara, *et al.*, 2014). These studies did not as such consider IBL teaching approach for students to acquire SPS and how it affects academic achievement. The effects of IBL in learning SPS in Biology subject are understudied. This study therefore sought to investigate the effect of IBL on both basic and integrated SPS acquisition level and achievement in Biology.

From the studies reviewed gender has been identified as a factor that affects academic achievement (Abungu *et al*., 2014). In the present study gender was considered as a moderating variable. So far studies that have been conducted to determine interaction effect of teaching method used and gender did not address IBL as a teaching method and also these studies were conducted outside Kenya. Therefore there was need to establish if there was an interaction effect between IBL and gender on students' academic achievement in Wareng Sub-Ccounty of Uasin-Gishu County, Kenya.

2.9 Summary of Chapter

This chapter covered the overview of the reviewed literature. It outlined general literature on inquiry-based learning which covered the principles of IBL, related literature in IBL and Biology Education, Science Process Skills-the basic and integrated Science Process skills, inquiry-based learning and acquisition of Science Process skills, inquiry-based learning and academic achievement, gender and academic achievement, critique of literature reviewed. The next chapter discusses the research design and methodology.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Overview of the Chapter

This chapter constitutes a discussion of the research paradigm, study area, research methodology, research design and the sample population. Along with these are the sample size and sampling procedures, variables of study, research instrumentation (a description of the type of tools that were used along with the requisite validity and reliability considerations). Data collection procedures; data analysis and ethical issues were considered.

3.2 The Research Paradigm

A research paradigm is a set of fundamental assumptions and beliefs as to how the world is perceived; it serves as a thinking framework that guides the behaviour of the researcher (Jonker & Pennik, 2010). Further noting, Neuman (2011) emphasizes that it is important to initially question the research paradigm to be applicable while conducting research as it substantially influences how one undertakes a social study from the way of framing and understanding the social phenomena. The selection and capability of the research paradigm that was used in this study to understand the effect of IBL on the acquisition and achievement of Science Process Skills in Biology subject is rooted in the underlying beliefs the researcher holds about the fundamental nature of the objectives of this research. These beliefs are summarized by the study's position related to the ontological, epistemological and methodological nature of society and social science.

Ontology refers to assumptions held about the nature of social reality while epistemology is defined as the theory of knowledge embedded in the theoretical perspective and thereby in the methodology (Creswell, 2009). According to Lindsay (2001), ontological and epistemological assumptions together make up a paradigm. Therefore, a paradigm can also be considered as a collection of logically related assumptions, concepts or propositions that orient thinking and research (Lindsay, 2001).

The matter of knowing about the effectiveness of IBL on students' acquisition, and achievement of Science Process Skills in Biology subject in Wareng Sub-County by stakeholders is an epistemological one. The epistemology of effectiveness of IBL as an instructional strategy in this study is important in understanding pedagogies that are suitable for secondary school curriculum instruction. Both observable phenomena and subjective meanings can provide acceptable knowledge dependent on the research questions (Wahyuni, 2012). The view chosen by the study to best achieve answers to research questions is an ontological one (Neuman, 2011). The epistemological and ontological underpinnings of the research questions posed in this study required an understanding of respondents' knowledge about the impact of IBL as an instructional method in teaching Biology at secondary school level in Wareng Sub-County of Uasin-Gishu County.

This study was guided by the pragmatist approach. Pragmatist proponents start off with the research question to determine their research framework. They emphasise that one should view research philosophy as a continuum, rather than an option that stands in opposite positions (Jonker & Pennik, 2010; Wahyuni, 2012). Pragmatism believes that objectivist and subjectivist perspectives are not mutually exclusive.

Hence, a mixture of ontology, epistemology and axiology is acceptable to approach and understand social phenomena. The emphasis here is on what works best to address the research problem at hand. Therefore pragmatist researchers favour working with both quantitative and qualitative data because it enables them to better comprehend social reality (Wahyuni, 2012). Therefore, the methodology, design and implementation of the research were situated in the study's own world view and learning experiences which oscillated between quantitative and qualitative methodologies. The study tried to make a fix of both methodologies; introducing them separately before illustrating their convergence and how they apply.

3.3 Research Methodology

According to Creswell (2009), research methodology refers to the plans and procedures for research that span the decisions from broad assumptions to detailed methods of data collection and analysis. This study adopted a concurrent mixed method approach which encompasses both a qualitative and quantitative component. It is useful in helping researchers meet the criteria for evaluating the quality of their answers (Tashakkori & Teddlie, 1998) better than the single approach method. A mixed method research is an approach to inquiry that involves the integration of philosophical assumptions, the use of both quantitative and qualitative approaches and the mixing of both approaches in a study. It is more than simply collecting and analyzing both kinds of data. It also involves the use of both approaches in tandem so that the overall strength of a study is greater than either one of the two approaches (Creswell, 2009).

The combination of research methods helps complement the advantages of each methodology with that of the other thus making a stronger research design that will yield more valid and reliable findings. More so, the inadequacies of individual methods will be minimized and more threats to internal validity can be recognized and addressed (Creswell, 2009). Literature by Greene and Caracelli (as cited in Aloka, 2012) collaborates that mixed methods have the potential of enabling researchers to comprehend better, generate insights deeper and broader and to develop important knowledge claims that respect a wider range of interests and perspectives. They offer significant potential enabling us to understand better the complex social phenomena which we know.

3.4 Research Design

This study was a quasi-experimental design because intact comparative groups that is convenient and in place was used. Secondary school classes exist as intact groups and school authorities do not normally allow the classes to be dismantled and reconstituted for research purposes (Shadish, Cook & Campbell, 2002). Quasi-experimental research is widely used in the evaluation of teaching and learning interventions because it is not practical to justify assigning students to experimental and control groups by using non-random assignment (Randolph, 2008). Quasi-experimental research design also offers the benefit of comparison between groups because of the naturally occurring treatment groups (Cohen, Manion & Marrison, 2007).

The scientific design that was employed for this study is the Solomon fourfold non-equivalent control group design. This design overcomes weaknesses of external validity that may occur in other designs and also allows for more vigorous control through the use of two control groups when compared with other experimental designs, thus also controlling the major threats to internal validity except to those due to maturation, interaction, history and instrumentation (Sekaran, 2006). Solomon fourfold non-equivalent group control design involves forming two experimental and two control groups for the study. Table 3.1 illustrates the research design that was used for this study. O_1 and O_3 are the pre-test; O_2, O_4, O_5 and O_6 are the post-tests; 'X' is the teaching intervention/treatment where students were instructed using IBL. The broken lines dividing the rows show that assignment of students to the control and experimental group was by non-random assignment.

Table 3. 1: Solomon Fourfold Non-Equivalent Group Control Design

GROUP	PRE-TEST	TREATMENT	POST-TEST
Group 1	O_1	X	O_2
Group 2	O_3		O_4
Group 3		X	O_5
Group 4			O_6

Source: Adapted from Sekaran (2006)

The experimental groups (group 1 and 3) were exposed to the treatment (IBL) and the control groups (group 2 and 4) continued to be exposed to the TL by use of conventional methods such as lecture method. Group 1 was experimental group 1; it received a pre-test, treatment 'X' (IBL) and post-test. Group 2 was control group 1; it received a pre-test, followed by the control condition (TL) and post-test. This group helped to establish whether or not; testing, regression, maturation or history is a threat to internal validity. Group 3 was experimental group 2; it received the treatment (IBL) and post-test but no pre-test was administered. Group 4 was control group 2; it received the normal traditional learning approach and a post-test only. This group helped to establish whether or not alterations in the post-test scores of the experimental group were as a result of combined effects of history and maturation by comparing O_6 with O_1 and O_3. The effect of history or past experiences of the learners was checked by establishing the entry behaviour of the students. The initial behaviour of the respondents was established through a pre-test for experimental group 1 (group 1) and control group 1 (group 2). The pre-test helped to establish the level of learners at the beginning of the study. Students of the same class who were of the same age bracket (17-18 years) participated in the study, thus maturation was not a threat to internal validity. The details of activities that were carried out in the four groups are shown in Table 3.2.

An assertion made by Mubichakani (2012), is that the pre-test can be considered as an intervening variable in a study, in the sense that it may have an impact on the post-test scores. As a result of the effect the pre-test can cause, experimental group 2 (group 3) and control group 2 (group 4) were established to check on the effect of the treatment on the post-test scores. This was achieved by not administering a pre-test to experimental group 2 and control group 2.

Table 3. 2: Activities in the Solomon Fourfold Non-equivalent Control Group Design used in the Study

Group	Pre-test	Treatment	Post-test	Questionnaire
Experimental group 1	Administered	IBL	Administered	Administered
Control group 1	Administered	TL	Administered	Not Administered
Experimental group 2	Not Administered	IBL	Administered	Administered
Control group 2	Not Administered	TL	Administered	Not Administered

3.5 Study Area

The study was conducted in Wareng Sub-County within Uasin-Gishu County. Uasin-Gishu County is located in the northern part of the Rift Valley, also known as the North-Rift region. The location of Wareng Sub-County in Uasin-Gishu County is illustrated in Appendix II. In addition the neighbouring Counties are Nandi and Kakamega to the West, Trans-Nzoia to the North, Elgeyo-Marakwet to the East, Kericho and Baringo County to the South. Wareng Sub-County has an area of 989.1 square kilometres and comprises of two administrative divisions, Kesses (692.1 km^2) and Kapsaret (297 km^2) (Wareng Sub-County Statistics office, 2014). The region's altitude ranges from 2,700 metres above sea level at Timboroa in the East to about 1,500 metres above sea level at Kapsaret in the West (Eldoret South Constituency, 2009).

The area has red loam, red clay, brown clay and brown loam soil types. Rainfall in the area is high, reliable and evenly distributed with the average rainfall ranging between 900 millimetres and 1,200 millimetres. Moreover, the rainy season occurs between the months of March and September with two distinct peaks in May and August. The wettest area is Kapsaret Division. Temperatures range between 8.4ºC and 26.1ºC (ibid). The main economic activities in Wareng Sub-County are crop farming (38%) of which the major crop is maize, livestock farming (32%) and trade/business - 18% (Eldoret South Constituency, 2009). Majority of the farmers are peasant farmers and depend on the household for farm labour. Owing to the high poverty levels (ibid); most of the parents encounter challenges on raising school fees for secondary school children.

Wareng Sub-County is endowed with higher institutions of learning such as Eldoret National Polytechnic; which offers certificate, diploma and higher diploma in technical and applied courses, Catholic University of Eastern Africa (CUEA)-Gaba campus and Moi University both of which offer Teacher Education programmes. This provides teachers with the opportunity to access and benefit from refresher courses on pedagogies such as IBL. The expectation is that teachers in this region should be familiar with instructional methods such as IBL thus improve on their competence in content delivery. Unfortunately this is not the case as is portrayed by the examination results from this region.

Wareng Sub-County was chosen because of its low performance (recorded the lowest mean among the three Sub-Counties in Uasin-Gishu County) in Biology Wareng Sub-County Secondary School Pentagon Joint Examination (WSCSSPJE). Wareng Sub-County recorded a mean of 3.248 (SCEO-Wareng, 2015b), which is a ‘D’ grade compared to the other two Sub-Counties of Uasin – Gishu County (Eldoret West and Eldoret East) which recorded a mean of 4.021 and 4.201 respectively in their term one joint examinations (SCEO-Eldoret West, 2015; SCEO-Eldoret East, 2015). These mean scores translate to a ‘D+’ grade. The pass mark is defined by marks that fall in the ‘D+’ grade and above

3.6 Study Population

The study targeted Form three students from public secondary schools in Wareng Sub-County. It comprised of 51 public secondary schools as at the time of the study; of which the Extra County and County schools are seven, private schools are three and 41 are Sub-County schools (SCEO-Wareng, 2015b). Out of the 41 Sub-County schools, 36 are of the mixed day category schools. Only 25 schools in the mixed day category had students up to Form three level at the time of the study. The total population of Form three students studying Biology in public secondary schools of Wareng Sub-County was 2,594 (SCEO-Wareng, 2015b).The target population of this study was selected from the mixed day school category. This is because students from this category recorded lower mean scores compared to those in boarding and single sex schools with reference to their achievement in Biology subject. Therefore there was a need to examine whether IBL as an instructional strategy influences their acquisition of SPS and academic achievement in Biology subject.

3.6.1 Sample Size

According to Patton (2002) the sample size depends on the purpose of the inquiry, the stake, usefulness of inquiry, credibility and utilisation of the available time and resources. The sample size comprised of the students from four intact classes that were selected from four schools. According to Mugenda and Mugenda (2003) and Fraenkel and Wallen (2000), the recommended minimum size should be 30 students per group. The classes that were used for this study comprised of a minimum of 45 students each.

3.7 Sampling Techniques

The unit of sampling was the secondary school. Secondary schools operate as intact groups (Randolph, 2008) because of the organization of the instruction levels (Form one to four). This study employed stratified, systematic and simple random sampling techniques so as to come up with a representative sample population that enhanced generalization of the research findings since it was not possible to seek the views of everyone for generalization of results (Cohen, Manion & Morrison, 2007). Sampling techniques for selection of the schools and students to participate in the study included stratified sampling, systematic sampling, and simple random sampling.

3.7.1 Stratified Sampling

The schools in Wareng sub-county were grouped into different categories such as boys' boarding, girls' boarding, mixed day and boarding and mixed day schools. After grouping the schools, the mixed day schools were then selected for participation.

3.7.2 Systematic Sampling

Wareng sub-county consists of a total of 41 mixed sex schools. Out of these 41 schools, only 25 schools had students up to Form three level, as at the time of the study. Systematic sampling was used to select four mixed day schools from the 25 schools because of the preferred Solomon fourfold non-equivalent group control design. A list of the 25 mixed day schools was obtained from Wareng sub-county education office; this list provided the sampling frame. The first school on the list was picked, after which from the remaining 24 schools every eighth count in the list was selected. This provided a total of four schools that were used in the study.

3.7.3 Simple Random Sampling

Simple random sampling was used to assign the four selected schools into the Control and experimental groups. At Form three level, students are only allowed to select two Science subjects that are examined in KCSE. Schools that have more than one stream usually form a subject combination as Biology and Chemistry, Physics and Chemistry or Biology and Physics to cater for placement on stream-basis and easy time tabling. That is, streams are referred to as Biology and Chemistry, Physics and Chemistry or Biology and Physics class. In this study only one school had more than one stream, the streams were presented as Biology/Chemistry and Physics/Chemistry, for this case the Biology/Chemistry stream was used for the study. Three of the schools had a single stream, thus the intact classes were used in the study. The study sample was made up of 220 students.

Table 3. 3: Number of Respondents used in the Study

Group	Gender		Frequency	Percentage
	Male	**Female**		
Experimental group 1	30	22	52	23.64
Experimental group 2	29	27	56	25.45
Control group 1	37	27	64	29.09
Control group 2	27	21	48	21.82
TOTAL	**123**	**97**	**220**	**100.00**

Source: Research Data, 2016 *N* = 220

3.8 Variables of the Study

A variable can be considered as an operational construct or particular property in which the researcher is interested (Cohen, Manion & Morrison, 2007).

3.8.1 Independent Variables

An independent variable is an input variable, that which causes, in part or in total, a particular outcome. It is a stimulus that influences a response, an antecedent or a factor which may be modified (e.g. under experimental or other conditions) to affect an outcome (Cohen, Manion & Morrison, 2007). The independent variable is also called predictor variable because it predicts the amount of variation that occurs in another variable (Mugenda & Mugenda, 2003). The independent variable in this study was the treatment or teaching intervention, in other words IBL based on the 5E learning model. The independent variable was measured by determining its effect on the dependent variables in terms of level of acquisition of SPS and achievement in the BSPSAT.

3.8.2 Dependent Variables

A dependent variable, on the other hand, is the outcome variable, which is caused, in total or in part, by the input or antecedent variable. It is the effect, consequence of, or response to an independent variable (Cohen, Manion & Morrison, 2007). A dependent variable attempts to indicate the total influence arising from the effect of the independent variable and it varies as a function of the independent variable (Mugenda & Mugenda (2003). The dependent variables in this study were students' acquisition level and achievement of SPS in Biology subject. Acquisition of SPS was determined by measuring the level of acquisition of various skills using a BSPSQ, the mean score and percentage of each skill was used to establish acquisition level among the learners. Achievement in Biology was measured using a BSPSAT and the mean achievement score; *t*-test was used to determine the equality of means in the pre-test and post-test scores in the experimental and control groups. This helped to establish the effectiveness of IBL

3.9 Research Instruments

According to Kombo and Tromp (2006), social sciences commonly use questionnaires, interview schedules, observational check lists and standardized test as research instruments. This study used both quantitative and qualitative data collection techniques. Achievement tests, questionnaires and observation checklist were used as data collection instruments.

3.9.1 Test

The Biology Science Process Skill Test–BSPSAT (Appendix III) was administered to the respondents so as to assess their SPS achievement in the ecology topic in secondary school Biology course. The BSPSAT was constructed from the KCSE past examination papers which were then modified so as to be suitable for the study. The test items were constructed from the ecosystem sub-topic of the ecology topic of Form three Biology syllabus. Structured questions were used and the respondents were expected to elicit short answer responses. During construction of items, care was taken to eliminate any extraneous factors that might prevent the students from responding to the questions. Items that measured achievement in terms of the application of SPS were selected.

The BSPSAT was administered at two levels: before the teaching intervention (as a pre-test) and after the teaching intervention (as a post-test) to allow for comparison of the scores. The BSPSAT comprised of 10 questions, total marks were 35 marks, the post-test had the questions shuffled to minimise the effect of familiarity of the questions. The BSPSAT – pre-test and post-test assessed on SPS application in terms of achievement. The BSPSAT was developed on the basis of the research objectives and specific BSPS and ISPS as defined in the study variables as captured in the conceptual framework and literature review. The test items evaluated different SPS, the distribution of questions on basis of SPS and loading of marks is illustrated in table of specification of SPS (Appendix IV). The explanation for scoring the BSPSAT is shown in a rubric (Appendix V). The test was suitable for this study because it enabled the researcher to measure the learners' level of acquisition of SPS and achievement in Biology.

3.9.2 Questionnaire

A questionnaire, Biology Science Process Skills Questionnaire–BSPSQ (Appendix VI) was administered to collect data from the respondents in the experimental group on their views concerning IBL as an instructional approach. The students responded to the questionnaire after the treatment period. According to Kothari (2008), questionnaires are usually free from the interview bias as the answers are in the respondent's own view. Respondents also have adequate time to give well thought out answers. Questionnaires are also time-saving and information can be collected from a very large sample. The choice of using a questionnaire was therefore based on these reasons as well as the fact that it is appropriate for literate, educated and co-operative respondents where in this case all respondents of the study were considered to meet these requirements.

The questionnaire was developed on the basis of the first objective of the study and variables as captured in the literature review. The questionnaire was also appropriate for this study as it enabled the researcher to gather focused information since the respondents interacted with the questionnaire but not the researcher. Each of the 220 respondents as stated in the sample size was issued with a copy of the questionnaire to fill. The questionnaire contained two parts: Part I was on demographic data of the respondents and part II had statements with regard to the effectiveness of the teaching method (IBL) used on acquisition of Science Process Skills in secondary school Biology. The questionnaire consisted of close-ended questions which adopted a five point Likert scale ranging from strongest concurrence (5 points) through undecided concurrence to no concurrence (1 point) in response to a particular statement.

3.9.3 Observation Check List

Observation as a research process, offers an investigator the opportunity to gather 'live' data from naturally occurring social situations (Cohen, Manion & Morrison, 2007). Observation as a method of collecting research data, involves observing behaviour and systematically recording the results of those observations (Sheroz, 2015). Observation as a way of data collection overcomes the weakness of questionnaires in the sense that it does not rely on a participant's willingness to provide information (Sheroz, 2015). The researcher does not rely on second hand information but on their own ability to obtain information from participants by recording what he or she has witnessed (Cohen, Manion & Morrison, 2007). A non–participant observation approach was employed because the researcher observed the classroom activities during the study but did not participate in these activities. A Biology Science Process Skills Observation Checklist (BSPSOC) was used to record the observations made during the study. Two lessons were observed, that is, one lesson for each experimental group using the BSPSOC (Appendix VII). Event sampling was used to record tally marks each time the preferred behaviour was observed against the statements in the BSPSOC. The number of tallies for each statement was used to record the number of occurrence (frequency) of an observed behaviour of the SPS among the students.

3.9.4 Treatment

This study was conducted for four weeks. From the four selected schools, two classes from two schools were assigned to the experimental group and were instructed using IBL through 5E learning model and the other two classes from the other two schools were assigned to the control group and were instructed through conventional TL approach. A group in each school was instructed by the same teacher on the same content of the Biology course. The teachers who taught the experimental groups were trained on the implementation of the IBL using the 5E learning model before the treatment period commenced. During the instruction, the ecosystem concepts were covered as per the Ministry of Education Science and Technology (MoEST) KICD curriculum. The classroom instruction of the groups was regularly scheduled for five lessons per week (as stipulated in the syllabus) in which each teaching session lasted 40 minutes and 80 minutes for a practical lesson.

The study was done using the Solomon fourfold control group design with the BSPSAT as the test that was used to measure students' acquisition and achievement of SPS in the unit of ecosystems in Biology subject. Biology SPS achievement test was also given as a pre-test to students in experimental group 1 and control group 1 at the beginning of the study to determine whether there would be a significant difference between the groups with respect to their achievement of SPS. In the control groups, the teacher employed the conventional traditional learning method. The students were instructed with regularly designed Biology lessons, as is done with the day to day teaching. During the classroom instruction, the teacher majorly used lecture, question and answer methods to teach Biology subject.

The experimental groups were instructed by using IBL through the 5E learning model. According to this method, Bybee's 5E phases were arranged in a sequence to allow for meaningful learning to occur. In the first phase (engagement), the teacher asked the students some questions at the beginning of the lesson in order to arouse interest and generate curiosity in the topic of study, raise questions and elicit responses from students that provided an idea of their prior knowledge. In the second phase (exploration), students were allowed to carry out an investigative task and discuss the question in groups by using their previous knowledge related to ecosystems. During these discussions the teacher allowed the students manipulate materials to actively explore concepts, processes or skills.

The teacher played the role of a facilitator; observing and listening to students as they discussed in groups. Each group presented a common answer to the teacher after discussion. This way, the teacher had an opportunity to analyse the students' previous ideas. The third phase (explanation), was based on the students' answers, the teacher explained the concept using students' previous experiences. The teacher also presented a scientifically correct explanation by using examples from daily life in order to make concepts more concrete. At the fourth phase (elaboration) students worked in groups again. The purpose of this phase was to extend conceptual understanding through practice of the desired skills so as to deepen understanding. Lastly, in the fifth phase (evaluation) the teacher encouraged students to assess their understanding of the concept taught and the abilities that enabled them perform the given task. Learners were then evaluated on their learning outcome. Before presenting each new concept, the teacher asked questions which students attempted to answer by using their previous knowledge.

3.9.5 Treatment Procedure

A sample of the treatment procedure for IBL lessons that were used to administer IBL (Appendix VIII) using the five stages of the 5E learning model has been presented in the sample lesson plan below in the sample lesson guide.

Sample lesson guide

Class Discussion

TOPIC: Ecology

Subtopic: Concepts of Ecology

Time: 40 minutes

Objective of the lesson.

By the end of the lesson the learners should be able to:

i) Define the term Ecology

ii) State the concepts of ecology.

Teacher grouped the learners into small groups of 8-9 students

Teacher guided the learners through the phases of 5E learning model.

Engagement

Teacher asked the students to discuss the following questions in their groups

1. Name the branches of Biology
2. From the answers provided in (1) above, which branch deals with the living organisms external surrounding?

After discussing the groups presented their answers.

This stage allowed the teacher to determine the learners' prior knowledge.

Exploration

The teacher asked the students are to search for the meaning of terms used in ecology.

Autecology, synecology, habitat, ecological niche, population, community, ecosystem, biosphere, biomass and carrying capacity.

Explanation

The teacher engaged the class in a discussion (in their groups)

The teacher asked the learners to answer the following questions in their groups

1. What is the difference between the following terms:
    - i) Autecology and synecology
    - ii) Habitat and ecological niche
    - iii) Population and community
    - iv) Ecosystem and biosphere
    - v) Biomass and carrying capacity

Learners presented the answers to the questions as the teacher listened.

The teacher corrected the learners where answers were wrong and introduced relevant vocabulary or terminologies so as to provide correct answers.

The teacher also asked students questions on the terminologies introduced to ascertain that learners understood the teachers' explanation

Elaboration

The teacher presented photographs of animals in different environments (terrestrial and aquatic).

Learners *observed* the photographs (A and B) and answered the following questions

1. What is the ecological niche of earthworms in photograph A?
2. a) Which photograph illustrates the concept of synecology?

   b) Explain your answer in 2(a) above.

Evaluation

To demonstrate an understanding of knowledge of the concept and skills, the teacher evaluated students own progress and knowledge by asking the following questions.

1. Define ecology and ecosystem.
2. Give examples of ecosystems
3. Distinguish between biomass and carrying capacity

The control group was instructed using the traditional or ordinary lesson plans (Appendix IX). These lesson guides outlined an introduction which introduced the lesson, lesson body that consisted of the lesson development and a conclusion that summarised the lesson

3.10 Validity of Research Instruments

Validity refers to the accuracy of inferences which are based on the research findings and how meaningful they are (Golafshani, 2003; Cohen, Manion & Morrison, 2007). Validity may also imply the degree to which results from analysed data actually represent the problem under study (Alvesson & Skoldberg, 2000). This study focused on the following to check on the research instruments validity.

3.10.1 Content Validity

The content validity of a measuring instrument is the extent to which it provides adequate coverage of the investigative questions guiding the study. If the instrument contains a representative sample of everything that is of interest, then the content validity is good (Brewer, 2000; Ross, 2005). Content validity of the questionnaire and test was reviewed by six experienced secondary school Biology teachers who are also KCSE Biology examiners.

3.10.2 Face Validity

This was done by ascertaining whether at face value the questions appeared to be measuring the construct as per the research objectives. Therefore face validity indicates how an item intends to measure a concept, based on the look of it. That is, the instruments provide adequate coverage of the concept in question. This was observed to ensure that the instruments provided adequate coverage of the study concepts. This is dependable on the knowledge of how the people respond to the questions (Brewer, 2000; Ross, 2005). The items were assessed by Biology subject teachers and the research supervisors for the appropriateness of the items for the purpose of the investigation and representativeness of the ecosystem unit of the secondary Biology course.

3.10.3 Construct Validity

This refers to the appropriateness of inferences made on the basis of observation or measurements (often test scores). Specifically, it seeks to establish whether a test measures the intended construct (Brown, 1996). The BSPSAT was validated by peers and research supervisors to ascertain that the questions asked elicited responses that measured the research objectives.

3.11 Reliability of Research Instruments

Reliability is a measure of the degree to which a research instrument yields results after repeated trials. Reliability is used to measure precision and accuracy. An attitude scale is considered reliable, for example, to the degree to which the same respondents, or very similar respondents, receive the same or very similar scores upon repeated testing (Ross, 2005).

3.11.1 Pilot Study

Piloting is important to establish both the reliability and content validity of the instrument and to improve questions, formats and scales (Ross, 2005). A pilot study was carried out in two schools of Eldoret West sub-county which had similar characteristics as the study area. The pilot study was conducted in Eldoret West sub-county so as to avoid a halo effect on the study area. The results from the piloting were incorporated in the revision of the final instruments and helped to improve their content validity as well as questions, format and scale reliability (ibid).

3.11.2. Reliability of the Questionnaire (BSPSQ)

The responses of the questionnaire (BSPSQ) from the pilot study were used to determine the reliability of the instrument. The reliability coefficient of the BSPST was estimated using Cronbach's alpha, which is a statistic that is used to provide a measure of internal consistency or reliability of a test or scale (Tavakol & Reg, 2011). It is expressed as a number between 0 and 1, since it is a ratio of two variances. Empirically, however, alpha can take on any value less than or equal to one. However, higher values of alpha are more desirable. Some scholars, as a rule of thumb require a reliability of 0.70 or higher before they can use an instrument (Nunnally, 1978).

The internal consistency also describes the extent to which all the items in a test measure the same concept or construct (Tavakol & Reg, 2011). The 12 items on the BSPSQ were used to determine the reliability of the instrument using Cronbach's alpha coefficient. After the initial reliability test, three items in the BSPSQ did not measure the skill they were intended to measure; ambiguity in these questions was corrected to ensure the questions allowed learners to answer as was required. Different respondents were used to obtain a second set of data for the second reliability test. The reliability estimate for the BSPSQ was found to be 0.83. The reliability value of 0.83 was considered to be adequate as a measure of internal consistency estimate of reliability of the instrument.

3.11.3 Reliability of the Test (BSPSAT)

The scores of the test (BSPSAT) from the pilot study were used to determine the reliability of the instrument. The reliability coefficient of the BSPSAT was estimated using Kuder-Richardson formula 20 (*KR* 20). According to Gronlund and Linn's work (as cited in Lunz, n.d), the KR 20 formula estimates, as to whether the test items in the instrument measure the same characteristics. A reliability coefficient value greater than or equal to 0.7 is considered suitable for making possible group predictions that are sufficiently accurate. The 10 items on the BSPSAT were used to determine the reliability of the instrument using Kuder-Richardson 20 (*KR*-20). The reliability estimate for the BSPSAT was found to be 0.86. The reliability value of 0.86 was considered to be adequate as a measure of internal consistency of the instrument. Majority of the test items had item difficulty indexes of between 40% and 65%. Few items (numbers 2c, 3, 6 and 10b) had item difficulty indexes of less than 30%. The questions were revised to remove the difficult component.

3.11.4 Reliability of Observation Checklist (BSPSOC)

The 12 statements in the BSPSOC were used in the calculation of Cronbach's alpha so as to test whether the statements were reliable in measuring the first objective of the study. A Cronbach's alpha value of 0.83 was obtained. This implied that the BSPSOC has good internal consistency.

3.12 Data Collection Procedures

Data collection was done in two phases. The first phase involved the identification of teachers who were to be inducted on how to administer the treatment (that is, taught using IBL). During the first phase, teachers (who played the role of research assistants) were trained for five days on how to employ the 5E instructional model using IBL approach and ethical issues among other techniques of data collection. These ethical issues that were considered included: obtaining informed consent from participants, privacy and confidentiality concerns. The second phase entailed the teaching and learning process, administering of tests and questionnaire. The tests and questionnaires were administered to Form three students of the sampled schools and classes. The sampled schools were visited where the learning activities conducted by respondents in the experimental group were observed and recorded on how they applied the SPS.

3.13 Data Analysis

Data analysis involves organization, interpretation and presentation of collected data in order to reduce the field information to a workable size (Onen & Oso, 2005). The data analysis procedures chosen for this research were based on their applicability to the research method, the quasi-experimental nature of the research design and objectives of the study. The BSPSQ, BSPSOC and BSPSAT data were first subjected to preliminary processing through validation, coding, collating and editing and then tabulated in readiness for analysis using the Statistical Package for Social Science (SPSS), version 20 in relation to the research objectives. There were no missing or incomplete scores. After analysis, data was presented in tabular form using frequencies and percentages alongside inferential statistics. Percentages were used to determine and explain proportions.

Quantitative techniques such as descriptive statistics and inferential statistics were used to understand relationships between different variables, precisely, descriptive statistics. One-way ANOVA was used to determine if the four groups differed significantly among themselves on the experimental variables. Independent sample t-test statistics were used to determine the significant change on students pre-test and post-test score (test the difference between two means). Two-way ANOVA was used to determine the interaction effect of the main effects (teaching method and gender) on the achievement of BSPSAT.

3.14 Ethical Considerations for the Study

In addition to conceptualizing the writing process of the proposal, a researcher needs to anticipate the ethical issues that may arise during a study (Hesse-Bieber & Leavey, 2006). Research does involve collecting data from people and is about people (Punch, 2005). Researchers therefore need to protect their research participants, develop trust in them, promote the integrity of research, guard against misconduct or impropriety that might reflect on the researcher and institution and finally cope with new, challenging problems (Israel & Hay, 2006) that may arise during the study.

The following ethical issues helped enhance ethics during the study: Permission was first sought from the relevant authorities before conducting research. Approval was obtained to conduct research from the National Commission for Science, Technology and Innovation (NACOSTI) - Appendix X and XI. Permission was also sought from the county authorities to conduct research within their jurisdiction (Appendix XII). Likewise, permission was sought from the school administration so as to train teachers of Biology to teach using IBL and entry to the schools to conduct research in the schools selected. The respondents' participation was on voluntary basis; there were no rewards promised for participation. The respondents were also assured of privacy and confidentiality of the information obtained from them. The individual identity of the respondents was kept confidential; no information revealing the identity of any respondent was included in the final report. The schedule and routine on conducting the study were adhered to so as to ensure the research plan was followed.

3.15 Summary of the Chapter

This chapter constituted a discussion of the research paradigm which was founded on a pragmatist approach, as well as the study area-Wareng sub-county within Uasin-Gishu County. The mixed method was the methodology employed since it involved both qualitative and quantitative approaches, the research design comprised of a quasi-experimental design and used the Solomon fourfold non-equivalent group control design. Under the sample population, the items highlighted were: the sample size which comprised of 220 students. Stratified, systematic and simple random procedures were used to select the study sample. The variables of study were also discussed following which was the research instrumentation (a description of the type of tools that were used along with the requisite validity and reliability considerations). Finally, the data collection procedures, data analysis and ethical issues-such as the need to seek approval from the relevant authorities before conducting research-were included in this chapter. The next chapter presents the data analysis, presentation, interpretation and discussion of findings.

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION, INTERPRETATION AND DISCUSSION

4.1 Overview of the Chapter

This chapter presents the analysis, presentation, interpretation and discussion of data collected from the field. Information collected from the respondents was based on the research objectives and questions of the study. The required data was collected using the following research tools; BSPSAT, BSPSQ and BSPSOC which was analysed, presented and discussed on the basis of the research objectives. The chapter begins with the description of the characteristics of the groups of the respondents (demographic data), The chapter is subsequently arranged into three key sections which are based on the three research objectives that guided this study namely: (a) To determine the influence of IBL on students' level of acquisition of Science Process Skills in Biology subject; (b) To establish the difference between students achievement when taught using IBL approach and TL approach in Biology subject; and (c) To examine the interaction effect between IBL and gender on students' achievement in Biology subject.

4.2 Demographic Data

Before embarking on the main objectives of the study, there was need to understand the demographic characteristics of the respondents. The respondents of the study were Form three students who studied Biology whose demographic data is also presented in Table 4.1. The characteristics of the demographic data comprised of the students' gender and age.

Table 4. 1: Summary of Demographic Data of Respondents

Characteristics		**Frequency**	**Percentage**
	Male	123	55.91
Gender	Female	97	44.09
TOTAL		**220**	**100.00**
	15-16 years	0	0
Age	17-18 years	148	66.7
	Above 18 years	72	33.3
TOTAL		**220**	**100.0**

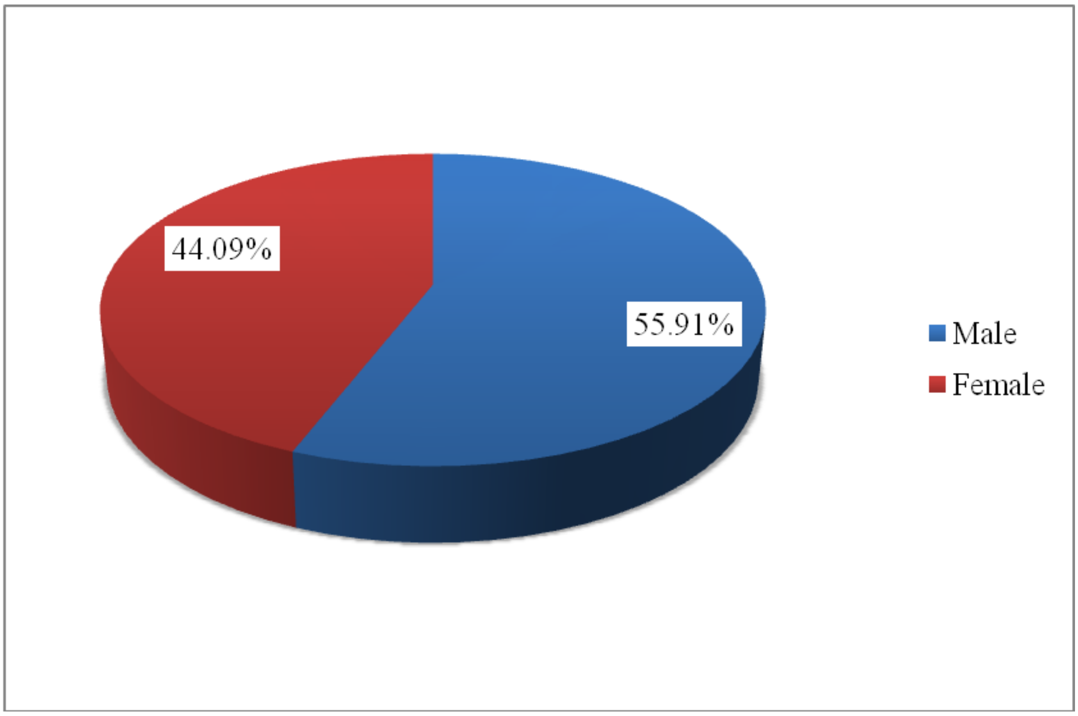
Source: Research Data, 2016 *N* = 220

4.2.1 Gender of Respondents

Table 4.1 presents the frequency and percentage of the gender and age of the respondents who participated in this study while figure 4.1 shows the distribution of the respondents in terms of gender. The male respondents were 123 (55.91%), of the total respondents whereas the female respondents were 97 (44.09%) of the total respondents. This data indicates that there is an almost achieved balance of male and female students in terms of representation in the study.

4.2.2 Age of Respondents

Table 4.1 presents summarised information on the age of the students who participated in the study. The findings revealed that 66.7% of the students' who studied Biology were in the age bracket of 17–18 years which is the expected age bracket for students at Form three. This age bracket can be attributed to the free primary education and the subsidized secondary school education policy. These policies have made funding of basic education to be the government's responsibility, making it possible for learners to access primary and secondary school education at the required age, which is at seven and 15 years respectively.



Source: Research Data, 2016 *N* = 220

Figure 4. 1: A Display of Percentages of male and female respondents of the study

However, 33.3% of the student respondents were aged above 18 years and none was aged between 15-16 years. This is an indication that some students were admitted to standard one after seven years of age or may have repeated some classes at either primary school or at the lower secondary level. Students who attend Day secondary schools often miss out on the learning process when they are sent home by the school administration due to incomplete school fees payment. This deters their ability to successfully complete the curriculum based on the Form level. For this reason some of them opt to repeat the class to effectively cover the curriculum content of the respective class.

4.3 Inquiry-Based Learning on Students' Level of Acquisition of Science Process Skills

The first objective of the study was to determine the influence of IBL on students' level of acquisition of Science Process Skills in Biology subject. This objective was based on the principle that Biology is a practical subject which aims at equipping students with concepts and skills that are useful in solving day to day problems in life. Once these skills are internalised, they can apply them in their daily life (MoE, 2003).

The extent to which IBL influences Biology students acquisition of SPS was measured by considering the following sub-variables, that is, the ability to: observe things critically, arrange biological information in an organised and orderly manner, accurately measure distances of objects in given units, use words, drawings and symbols to describe observations made during experiments and make inferences from information recorded during experiments. Also measured was the ability to: interpret data, control and measure variables in an experiment, formulate hypotheses of experiments, conduct experiments to obtain required information, obtain data about an object or an event's future state and lastly, display experimental or observational data in different forms such as graphs, diagrams and tables. The groups used for the first objective of the study were the experimental groups (that is, experimental group 1 and experimental group 2). Data was collected using a BSPSQ and a BSPSOC. The return rate of the questionnaire was 100%.

Data was collected and analysed under the research question "What is the mean score of students' acquisition of Science Process Skills in Biology when taught using IBL?"

To answer this question, means and standard deviations of each component skill from the BSPSQ have been used along with the BSPSOC for data triangulation. A descriptive analysis showing the percentages, means and standard deviations of students' responses exposed to IBL on the level of acquisition of BSPS in Biology subject is illustrated in Table 4.2.

Table 4. 2: Summary of the Percentages, Mean and Standard Deviations of Basic Science Process Skills

		Percentages				
No.	**Basic SPS**	**Agreed**	**Disagreed**	**Undecided**	**Mean**	***SD***
1.	Observing	76.9 (83)	19.2 (21)	3.7 (4)	3.93	1.273
2.	Classifying	80.6 (87)	16.6 (18)	2.8 (3)	4.09	1.196
3.	Measuring	72.3 (78)	20.4 (22)	7.3 (8)	3.90	1.311
4.	Communicating	62.9 (68)	27.8 (30)	9.3 (10)	3.57	1.389
5.	Inferring	67.6 (73)	24.1 (26)	8.3 (9)	3.79	1.305
6.	Predicting	73.2 (79)	21.3 (23)	5.5 (6)	3.82	1.281

Source: Research Data, 2016 *n* = 108

4.3.1 Basic Science Process Skills

The BSPS that were measured in this study included: observing, classifying, measuring, communicating, inferring and predicting. These skills are fundamental in providing groundwork for scientific inquiry such as ability to organise and describe objects and events (Sevilay, 2011).

4.3.1.1 Ability to Observe Things Critically

The ability to use the five senses to observe things critically is vital for learning, more so learning Biology subject. As a result, this study sought to establish whether IBL influences the students' ability to observe things critically so as to make correct explanations about what they see during Biology lessons. The respondents selected the most suitable choice as relates to their opinion towards this statement "Teaching method used helps me develop my ability to observe objects and events critically."

Majority (76.9%) of the respondents who were interviewed agreed to this statement. On the contrary, 19.4 % (21 respondents) were of the view that teaching method used did not help them develop the ability to observe things critically. A very small percentage (3.7%) of the respondents was undecided. The observation skill was ranked second with a mean of 3.93 and a standard deviation of 1.273 after the classifying skill. This study established that IBL has a positive effect on the level of acquisition of observation skill. Inquiry-based learning is learner-centred and involves activities or investigations that require students to work independently (Cruz, 2015); therefore they learn to observe objects and events to get the needed results. This observation concurs with conclusions drawn from studies conducted by Khan and Iqbal (2011) and Mutisya, Rotich and Rotich (2013).

4.3.1.2 Ability to Classify Biological Information

For a learner to properly perform an activity on classification there must be a high level of acquisition of the observation skill so that they are able to recognize the characteristics of objects, in terms of likeness and differences (Achor & Shikaan, 2015). In view of this observation, this study sought to find out if IBL as a teaching and learning approach has an impact on the learners acquisition of the classifying skill. The classifying skill was measured using the statement "Teaching method used helps me to arrange biological information in an orderly and organised manner." Majority (80.6%) of the respondents agreed that teaching method used helped them acquire and develop the classifying skill. The students were therefore able to arrange specimens into their appropriate groups using features that were observable.

During the study observations were made as to how the students organised and ordered biological information in the sub topics of food chains and food webs. In one of the lessons on feeding levels an observation that was made was that, majority (73.15%) of the students were able to rank organisms on the basis of how nutrients are transferred from the group of organisms that manufacture the food to other groups of organisms in the set up of their study. This indicates that teaching method used has an effect on the learner's capability to identify and organize biological information in the correct order so as to communicate the biological concept in question. On the other hand, a handful of the respondents (18) did not think that IBL had an impact on their ability to organise biological information so as to make it more meaningful. In a further analysis using the mean and standard deviation of each SPS measured, the classifying skill was ranked highest with a mean of 4.09 and standard deviation of 1.196. It can be noted that IBL had the greatest impact on the classifying skill. Similar results were established by Khan and Iqbal (2011) that indicated the classifying skill recorded the highest *t*-value among the SPS that were developed through IBL.

4.3.1.3 Ability to Measure Accurately

This study sought to establish the extent to which IBL affects the acquisition of the measuring skill among form three students who studied Biology. This was tested using the statement "I can measure distances in units given of objects and drawings." The study observed that majority (72.3%) of the respondents agreed that they were able to accurately measure distances in the required units of objects and drawings. On the contrary, 20.4% of the respondents did not consider an IBL approach of much help to them in acquiring and developing the measuring skill. The measuring skill recorded a mean value of 3.90 and standard deviation of 1.311. It was ranked fourth among the SPS measured in the study in terms of the acquisition level using IBL approach. If students acquire and develop the measuring skill appropriately, it gives them an opportunity to make value judgments when carrying out evaluations (Ango, 2002). In view of this observation, IBL is an effective teaching method that enhanced students' ability to measure units accurately.

4.3.1.4 Ability to Communicate Correctly

This study sought to find out whether IBL helped learners communicate their thoughts, ideas and findings from the experiments correctly. This was measured using the statement "Teaching method used helps me use words, drawings and symbols to describe observations made when conducting experiments." It was established that 62.9% of the respondents were of the opinion that teaching learning method used helped them to record the observations they make during the learning process appropriately and are thus able to present correct information and explanations to their classmates. Twenty seven percent of the respondents did not feel that their ability to communicate effectively is influenced by the teaching and learning approach (IBL). A small percentage (9.3%) of the respondents was unable to make a decision regarding how teaching learning method (IBL) used impacted on their ability to communicate their results from experiments they conducted. The communicating skill recorded a mean value of 3.57 and standard deviation of 1.389. It was ranked ninth among the SPS measured in the study in terms of the acquisition level using IBL approach. The mean value recorded by this skill is way above the mid value hence IBL was considered to be an effective teaching method that enhances the acquisition of the skill among learners. Students are required to be well-versed with the communicating skill because it is a critical aspect of scientific investigation. It helps them to disseminate their thoughts, ideas and findings from the experiments they conduct for awareness and learning (Ango, 2002). These findings are related to those established by Khan and Iqbal (2011). They observed that IBL was more effective in the development of the communicating skill when compared to Traditional Learning (TL).

4.3.1.5 Ability to Make Inferences

The study sought to know the extent to which IBL helps form three students of Biology to make inferences from information recorded during practical activities. The statement “Teaching method used helps me to make inferences from information recorded during experiments” was used to test the learners’ ability. The research established that 67.6 % of the respondents noted that teaching method used helped them to explain the observations they made during the practical sessions. This could be attributed to the fact that IBL allows learners to experience deeper understanding and a higher degree of reflection (Prince & Felder, cited in Spronken-Smith (2010), thus are able to relate various concepts in order to make meaning out of them as a whole component. On the other hand, 24.1% did not agree to the above statement while 8.3% were undecided. The inferring skill recorded a mean value of 3.79 and standard deviation of 1.305. It was ranked sixth among the SPS measured in the study in terms of the acquisition level using IBL approach. Therefore Inquiry-Based Learning (IBL) enhanced the learners' ability to acquire the inference skill by recording a higher level of acquisition among the other BSPS.

4.3.1.6 Ability to Predict

The study sought to find out whether IBL helps the students to make predictions using prior knowledge to obtain data about the future events of an experiment. The statement "Teaching method used helps me to use prior knowledge to obtain data about an object or an event's future state" was used to measure the level of acquisition of the predicting skill. The study established that majority (73.2%) of the respondents were of the view that teaching method used helped them to make predictions because they were able to relate what they already knew to determine the future outcome as was observed during lesson observations during the study. Application of prior knowledge is fundamental when using inquiry approach to learning. This is rooted in the constructivist learning theory, whose proponents argue that prior knowledge is prerequisite for new knowledge to be gained (Piaget, 1973; Vygotsky, 1978). According to Spronken-Smith (2010), IBL offers experiences that build on what students already know so that they can make connections to their existing knowledge structures, hence are able to relate existing knowledge to future outcomes. However, 21.3% of the respondents did not feel that the teaching-learning method used helped them to make predictions using prior knowledge to find data about the future state of objects or events, with 5.5% of the respondents undecided. The predicting skill recorded a mean value of 3.82 and standard deviation of 1.281. It was ranked fifth among the SPS measured in the study in terms of the acquisition level using IBL approach

4.3.2 Integrated Science Process Skills

The ISPS that were measured in this study included: interpreting skill, controlling variables, defining operationally, formulating hypotheses, experimenting and creating models. Integrated SPS are the immediate skills that are used in problem solving or conducting scientific experiments (Rambuda & Fraser, 2004). Learners are expected to combine BSPS with ISPS for greater application of SPS when investigating problems (Ongowo & Indoshi, 2013). The findings on ISPS are illustrated in Table 4.3.

4.3.2.1 Ability to Interpret Data

This study sought to establish how IBL influences Biology students' level of acquisition of interpreting data skill. The statement "Teaching method used helps me to interpret data" was used to test the learners' level of acquisition. The research found out that 72 (66.7%) respondents were of the opinion that teaching method used helped them in the acquisition of the interpreting data skill ranked seventh among the SPS measured in the study in terms of the acquisition level using IBL approach. Therefore IBL as an instructional approach highly influences the acquisition of interpreting data skill among Form three students of Biology. However, 30.5% of the respondents did not accept that the teaching-learning method used positively influenced the acquisition of interpreting data skill. The interpreting data skill recorded a mean value of 3.71 and standard deviation of 1.428. It was ranked seventh among the SPS measured in the study in terms of acquisition level using IBL approach.

4.3.2.2 Ability to Control Variables

This study sought to find out how IBL influences the students' level of controlling variables. The statement "Teaching method used helps me to control variables when carrying out experiments" was used to measure the learners' level of acquisition. The analysis indicated that 59.3% of the respondents (64 respondents) agreed that teaching-learning method used influenced how they acquired and developed the controlling variables skill. Observations made by the researcher during Biology lessons using BSPSOC (Appendix VII), noted that almost the same number of respondents (61 respondents) showed they were able to use the controlling variable skill.

However, 34.2% of the students disagreed with the statement that teaching method raised their level of acquisition of controlling variables skill. The controlling variables skill recorded a mean value of 3.44 and standard deviation of 1.487. It was ranked tenth among the SPS measured in the study in terms of the acquisition level using IBL approach.

Table 4. 3: Summary of the Percentages, Mean and Standard deviations of Integrated Science Process Skills

		Percentages				
No.	**Integrated SPS**	**Agreed**	**Disagreed**	**Undecided**	**Mean**	***SD***
1.	Interpreting Data	66.7	30.5	2.8	3.71	1.428
		(72)	(33)	(3)		
2.	Controlling	59.3	34.2	6.5	3.44	1.487
	Variables	(64)	(37)	(7)		
3.	Defining	55.6	36.1	8.3	3.37	1.470
	Operationally	(60)	(39)	(9)		
4.	Hypothesising	54.6	41.7	3.7	3.29	1.541
		(59)	(45)	(4)		
5.	Experimenting	75.0	22.2	2.8	3.91	1.281
		(81)	(24)	(3)		
6.	Creating Models	63.9	25.0	11.1	3.64	1.322
		(69)	(27)	(12)		

*values in brackets number of respondents

Source: Research Data, 2016 *n* = 108

4.3.2.3 Ability to Define Operationally

This study sought to establish whether IBL develops the students' ability to measure a variable in an experiment. The statement "Teaching method used helps me to develop my ability to measure a variable in an experiment" was used to test the learners' level of acquisition. The research established that 55.6% of the respondents (60 respondents) agreed that teaching method used developed their skill of defining operationally while 36.1% of them did not agree to this statement. A better observation on level of acquisition of defining operationally was established through triangulation of data when analyses of the BSPSQ and BSPSOC were compared. The findings from observations made during practical lessons using BSPSOC, indicated that only 51 (47.22%) students were able to apply the defining operationally skill. Conversely it was noted that the remaining students (57 students) were not able to explain how they obtained results based on the variables in the experiment. A group of students from experimental group 2 were unable to explain how they measured the environmental temperature of the area in which they were conducting their study. This implied that IBL as a teaching method did not positively impact on their ability to acquire and develop the defining operationally skill. The defining operationally skill recorded a mean value of 3.37 and standard deviation of 1.470. It was ranked eleventh among the SPS measured in the study in terms of the acquisition level using IBL approach. The defining operationally skill was among the skills that recorded low level of acquisition compared with other SPS measured. From this observation it can be implied that the defining operationally skill is difficult for the learners to comprehend hence a low acquisition level.

4.3.2.4 Ability to Formulate Hypotheses

This study sought to establish how IBL influences the ability of learners to form hypotheses of experiments they conduct. The statement "Teaching method used helps me to formulate hypotheses of experiments I design" was used to test the learners' level of acquisition. The study established that 54.6% of the respondents were of the opinion that teaching-learning method used helped them to correctly formulate hypotheses for the experiments they conducted. This claim was supported by the evidence of well formulated hypotheses for some practical activities in ecology on checking the students' practical reports. Findings indicated that 47 students were able to formulate hypotheses appropriately. The percentage of respondents that did not think the teaching method used helped them to formulate hypotheses of experiments they conducted was 41.7%. The formulating hypotheses skill recorded a mean value of 3.29 and standard deviation of 1.541. It was ranked last among the SPS measured in the study in terms of the acquisition level using IBL approach. This is an indication that students found this skill to be the most difficult to acquire and thus had challenges with its application.

4.3.2.5 Ability to Conduct Experiments

This study embarked on establishing how IBL influences the students' development of the experimenting skill. The statement "Teaching method used helps me to conduct experiments and obtain required information successfully" was used to test the learners' level of acquisition. The findings showed that majority (75%) of the students agreed that teaching method used developed their ability to conduct experiments by following given procedures to produce results. Contrary to this finding, few students (31) could not follow procedures correctly to produce the expected results. This evidence is supported by an observation made by the researcher during the conduct of Biology lesson observation, where students were unable to concretely understand the procedure of how to estimate the biomass of a certain grass species, and were therefore unable to determine the biomass of the vegetation in question during the practical lesson. Experimenting provides students with the experience to interact with apparatus. According to Chonji's work as cited in Ango (2002), this experience can have a highly significant relationship with the students understanding of Biological concepts. The experimenting skill recorded a mean value of 3.91 and standard deviation of 1.257. It was ranked third among the SPS measured in the study in terms of the acquisition level using IBL approach. Therefore IBL highly influences the acquisition of the experimenting skill; IBL can be used by teachers of Biology to develop this skill among learners so that they may conduct experiments in Biology subject effectively.

4.3.2.6 Ability to Create Models

Learners should be able to display experimental data in various ways such as using graphs, diagrams or tables so as to simplify the understanding of biological concepts. Therefore, this study sought to establish whether IBL helps students display experimental data using graphs, diagrams or tables. The statement "Teaching method used helps me to display experimental or observational data in different forms using graphs, diagrams and tables" was used to test the learners' level of acquisition. The findings of the study showed that 63.9% of the respondents (69 respondents) agreed that teaching method used helped them display information using graphs, diagrams or tables.

Observations made by observing practical activity reports prepared by the learners, indicated that 58 (53.7%) students showed that they could illustrate the feeding relationships of organisms in an ecosystem using food webs, food chains and pyramid of numbers. Some reports indicated that some students were not able to present information using illustrations such as food weds, food chains and pyramid of numbers clearly therefore understanding the process or event in question was difficult. This was observed from the small number of respondents (25%) who indicated on the

BSPSQ that teaching method used did not help them display experimental data accurately using graphs, drawings or tables. The creating models skill recorded a mean value of 3.64 and standard deviation of 1.322. It was ranked eighth among the SPS measured in the study in terms of the acquisition level using IBL approach. The implication that may be drawn from this analysis is that, IBL is effective to develop the creating model skill but its level of acquisition is lower than the interpreting data and experimenting skill among the ISPS.

4.3.3 Science Process Skills Using Biology Science Process Skills Observation Checklist (BSPSOC)

Two lessons were observed using the BSPSOC (Appendix VII) when conducting the study, one lesson from each experimental group. The students' practical reports were also observed to identify the students' level of acquisition and application for the SPS that were not observed during the classroom lessons. Data was collected and the frequencies on the observations made of students who illustrated an ability of using the SPS were recorded. The percentages of the frequency for each SPS were also calculated and are reported in Table 4.4.

Table 4. 4: Summary of Frequencies and Percentages of Basic Science Process Skills

No.	Basic Science Process Skill	Frequency	Percentage
1.	Observing	79	73.15%
2.	Classifying	83	76.85%
3.	Measuring	67	62.04%
4.	Communicating	64	59.26%
5.	Inferring	71	65.74%
6.	Predicting	72	66.67%

Source: Research Data, 2016 *n* =108

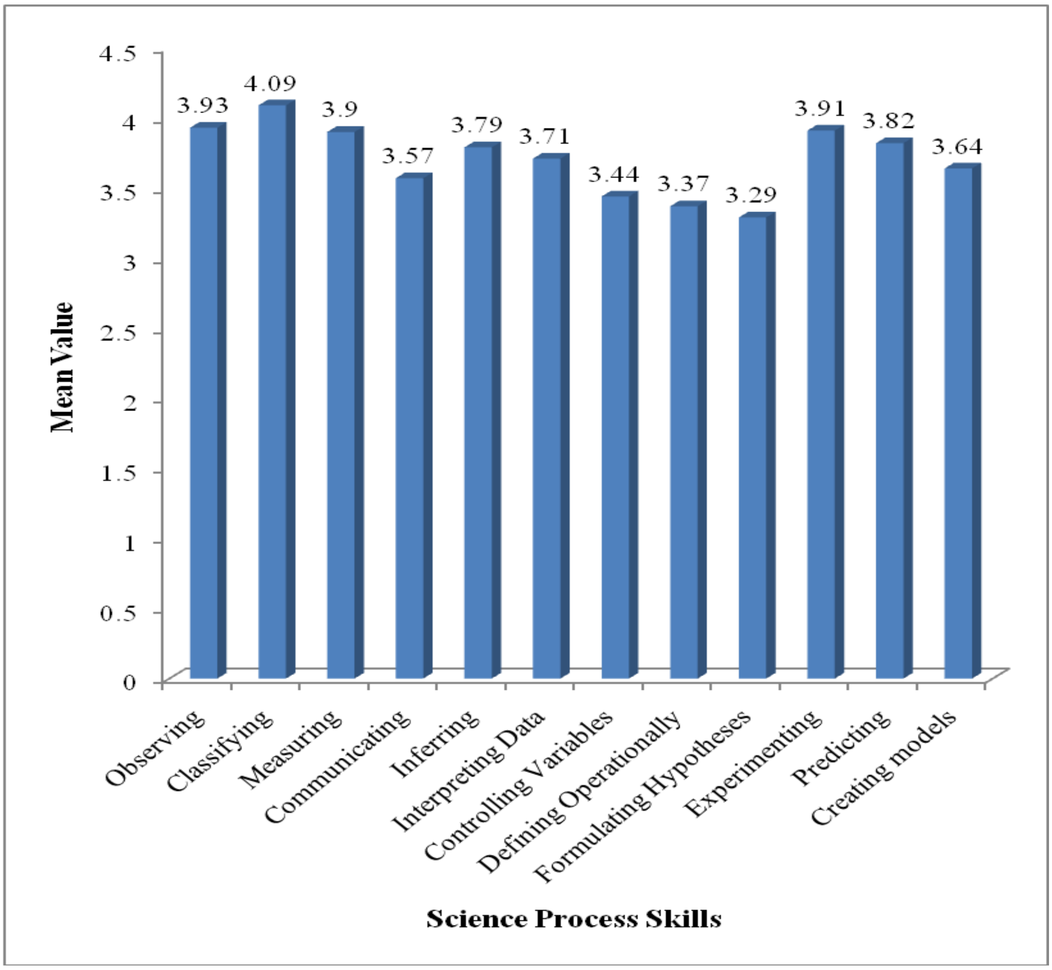
Table 4.4 shows the frequencies and percentages of the BSPS students acquired and applied during instruction and while making their practical activities reports. On comparing this data with the data obtained from the BSPSQ (Table 4.2), there is an indication that some BSPS recorded almost similar numbers of students on level of acquisition of SPS for given skill components. These skills include: observing (83, 79), classifying (88, 83), communicating (68, 64) and inferring (73, 71) on the BSPSQ and BSPSOC respectively. Table 4.5 below indicates the frequencies and percentages of the ISPS. A comparison of the number of respondents on agreeing to acquiring ISPS (Table 4.3) with observations made (Table 4.5) was also established, skills that recorded almost similar number of respondents were interpreting data (72, 70), controlling variables (64, 61) and experimenting (81,77) on the BSPSQ and BSPSOC respectively.

Table 4. 5: Summary of Frequencies and Percentages of Integrated Science Process Skills

No.	Integrated Science Process Skill	Frequency	Percentage
1.	Interpreting Data	70	64.81%
2.	Controlling Variables	61	56.48%
3.	Defining Operationally	51	47.22%
4.	Hypothesising	47	43.52%
5.	Experimenting	77	71.30%
6.	Creating Models	63	58.33%

Source: Research Data, 2016 *n* =108

The learning activities that students engaged in during the teaching-learning process enhanced the learners' ability and confidence to master and perform various SPS as is indicated by the results of both the BSPSQ and BSPSOC. These findings show that IBL was effective in enhancing level of acquisition of SPS among Form three students who studied Biology. After conducting a cross–observation of the findings of the BSPSQ and BSPSOC, findings indicated that learners recorded higher levels of acquisition in BSPS when compared with ISPS. This suggests that BSPS are mastered faster than ISPS.



Source: Research Data, 2016 *n* = 108

Figure 4. 2: Mean values of Science Process Skills

A graphic presentation of the 12 SPS in terms of their mean value is illustrated in figure 4.2. From the figure, it is observed that classifying skill has the longest bar, implying it has the highest rating. This means the classifying skill recorded the highest mean value while the hypothesising skill has the shortest bar (lowest rating). That is, it obtained the lowest mean value.

4.3.4 Discussion of Findings

During the teaching and learning process, learners should develop scientific skills; hence the teaching and learning process is important in enhancing the acquisition of SPS in Biology subject. The influence of inquiry as a teaching and learning approach needs to be determined so as to know whether it is an effective teaching and learning approach that may enhance the ability to obtain, learn and improve on the SPS among learners at secondary school level in Biology subject. The teaching and learning approach an instructor applies may influence the process of making learners accomplish the Science Process Skills that they use to learn Biology subject. Moreover, the process of acquiring these skills does affect how students improve in performing a given task (MoE, 2003).

According to Bybee and Deboer's work (as cited in Aydogdu, 2015), the acquisition of Science Process Skills is one of the most important aims of teaching science because the acquisition of SPS enables students to gain skills that are necessary in solving everyday problems (Kazeni, 2005). This study sought to establish the effect of teaching method (IBL) on level of acquisition of Science Process Skills in Biology subject among Form three students. From the findings established on the level of acquisition of SPS, it can be concluded that IBL leads to high level of acquisition for four BSPS. In order of rank using the percentages they are: classifying (80.6%), observation (76.9%), predicting (73.2%) and measuring (72.3%). In order of rank using mean values for the ISPS, experimenting skill (3.91) was ranked first followed by interpreting skill (3.71) and creating models skill (3.64) was ranked third. Data analysis indicated that the classifying skill was ranked highest by the respondents with a mean value of 4.09 and standard deviation of 1.196, while the hypothesizing skill is ranked the lowest with a mean value of 3.29 and standard deviation of 1.541.

Generally, the 12 SPS measured in the study achieved a mean value of above 2.5 which is considered satisfactory as relates to the level of acquisition of the SPS measured in this study. This implies that the views of learners on the effect of teaching method used on their level of acquisition of SPS are highly rated. This study presents findings that are similar to earlier studies that have been conducted on acquisition of Science Process Skills.

According to Ongowo and Indoshi (2013), common Science Process Skills that are examined at KCSE level include: observing, communicating, inferring, experimenting and interpreting of data. Findings from this study reveal that some common SPS examined at KCSE level identified by Ongowo and Indoshi recorded high mean values (i.e. observing, inferring, experimenting and interpreting data). This indicates that IBL can foster the acquisition of these skills and therefore enhance the performance of learners during practical activities and even at KCSE level. At the KCSE level, BSPS are examined more with the most featured skill being observation in comparison to the ISPS (Ongowo & Indoshi, 2013).

Observations made from this study indicate that the level of acquisition of the ISPS measured was lower than that of the BSPS. For example, the defining operationally skill acquisition level recorded a low mean value. This observation may be attributed to the minimal evaluation of the defining operationally skill at the KCSE level therefore teachers of Biology probably focus on the ISPS that are assessed in the

Biology KCSE such as interpreting data skill. These findings are in consonance with the findings made by Mohamad and Ong (2013).

Other than IBL enhancing acquisition of SPS, IBL also causes a positive impact on students' conceptual understanding of knowledge and Science Process Skills (Simsek & Kabapinar, 2010). This study also established that IBL enhanced students' performance in the post-test in the experimental groups, an indication of the positive impact of IBL on learners' acquisition and conceptual understanding of SPS. A study conducted by Nwagbo and Chukelu (2011), among senior secondary 1 (SS1) students in Abuja, Nigeria on the effects of biological practical activities method on students Science Process Skills acquisition established through hypothetical testing that practical activity method was more effective in fostering students' acquisition of Science Process Skills than lecture method.

Another study conducted by Achor and Shikaan (2015), among fifth grade students in Makurdi, Benue state of Nigeria, sought to determine the effects of field-based inquiry method of instruction on level of Science Process Skills acquisition by students. They established that students exposed to field-based inquiry method of instruction had significantly higher levels of SPS acquisition than those exposed to conventional strategy. The experimental group in Achor and Shikaan's study recorded a higher mean score (5.86) than the control group (3.80). The findings in Achor and Shikaan's study are in consonance with the findings of this study which have established that the SPS measured recorded mean values of above 2.5, thus IBL is effective in teaching ecology topic in Biology; ecology topic is mainly a field-focused topic. In addition, the findings of this study are also consistent with findings of Nwagbo and Chukelu (2011). This study established that the use of IBL to teach some practical aspects of ecology topic enhanced students' level of acquisition of Science Process Skills in Biology subject among form three students.

4.4 Inquiry-Based Learning and academic achievement in Biology

The second objective of the study was to establish the difference between students' achievement of SPS when taught using IBL approach and TL approach in Biology subject. This was determined by administering a BSPSAT (Appendix III) which tested on the following SPS; observation, classifying, measuring, communicating, inferring, interpreting data, controlling variables, defining operationally, hypothesizing, experimenting, predicting and creating models. Data was collected and analysed under the question "what is the difference between mean achievement score of students taught Biology using IBL and those taught using TL?"

Students' achievement can be evaluated by using different types of assessment; the common type is the achievement test. The marks students' score in any test or exam are usually a function of several attributes (Mubichakani, 2012). As a result of this observation, this study attempted to minimise the influence of any other factors on the BSPSAT scores other than those defined for the study (that is, inquiry-based teaching and learning approach). The initial behaviour of the respondents was established through a pre-test for experimental group 1 (group 1) and control group 1 (group 2). The pre-test helped to establish the level of learners at the beginning of the study. The pre-test mean score for experimental group 1 and control group 1 had no significant difference hence history was not a threat to internal validity.

All groups were exposed to the same post-test after administering a treatment intervention to group 1 and 3 (the experimental groups), so as to establish the significance in the mean difference of the test scores between the experimental and control groups. All students (i.e. all groups) in the study were given the post-test. None of the students were absent when the test was administered and thus attendance rate was 100%.

4.4.1 Pre-test Data Analysis

To achieve the second objective, data was collected using the BSPSAT. This test was administered in two phases–prior to the treatment as a pre-test and after the treatment as a post-test. The treatment was the IBL method. The results of the data analysis to answer the second research question that guided this study are presented in table 4.6.

Table 4. 6: Pre-test Means and Standard Deviations in BSPSAT

Variable	**Group**	***N***	**Mean**	***SD***	***SEM***
	Experimental Group 1	52	36.02	13.154	1.824
BSPSAT	Control Group 1	64	35.94	11.967	1.496

Source: Research Data, 2016 *n* = 116

The experimental group 1 and control group 1 were given a pre-test. The means of experimental group 1 and control group 1 were 36.02 and 35.94 respectively (Table 4.6). The means were rather low. A further observation of Table 4.7 shows that the two groups were almost equivalent on a level of Biological concepts in terms of applying SPS before the treatment. This is revealed by the mean difference (0.082) of the pre-test means between group 1 (experimental group 1) and group 2 (control group 1). This can also be observed by comparing the means of the two groups in the pre-test scores. To establish whether this difference was significant, an independent samples t-test was carried out, at a significance level of α = .05. The findings of this test are shown in Table 4.7.

Table 4. 7: *t*-test for Equality of Pre-test Means between Experimental Group 1 and Control Group 1

Variable	***t*-test for Equality of Means**				
	t	*df*	Sig. (2-tailed)	Mean Difference	Std Error Difference
BSPSAT	.035	114	.972	.082	2.336

Source: Research Data, 2016 *n* = 116

The independent samples *t* test had a *p* value of .972 as shown in Table 4.8. The *p* value (0.972) is greater than the alpha value (α = .05). Based on this observation, it can be inferred that there is no significant difference in the means of experimental group 1 (group 1) and control group 1 (group 2) in the pre-test. Hence, it was concluded that no group was better than the other in the pre-test, that is, the entry behavior of experimental group 1 and control group 1 was of the same level.

4.4.2 Post-test Analysis

After the administration of the pre-test to group 1 (experimental group 1) and group 2 (control group 1), group 1 (experimental group 1) and group 3 (experimental group 2) were taught using the IBL approach while group 2 (control group 1) and group 4 (control group 2) were taught using the regular TL approach. The IBL method was the treatment, thus only the experimental groups were exposed to this teaching method. The treatment period lasted for four weeks. At the end of the treatment period, all the four groups sat for a BSPSAT as a post-test to determine their achievement in SPS.

Data was analysed using *t*-test and analysis of variance (ANOVA) test *(F* test). Table 4.8 shows the BSPSAT post-test means obtained by the four groups. A comparison of the means of the four groups was done to establish if there are differences and the extent of dispersion for each group.

Table 4. 8: BSPSAT Post-test Means and Standard Deviations

Groups	***N***	**Mean**	**Standard Deviation**
Experimental group 1	52	60.58	13.17
Experimental group 2	56	59.25	12.87
Control group 1	64	47.13	9.73
Control group 2	48	41.20	13.89
All	**220**	**52.04**	**12.415**

Source: Research Data, 2016 N = 220

Results from Table 4.8 indicate that experimental group 1 (group 1) recorded the highest mean, followed by experimental group 2 (group 3), then control group 1 (group 2) and lastly control group 2 (group 4). A further observation made was that, the experimental groups (group 1 and 3) scored higher marks than the control groups (group 2 and 4) as depicted by their means. The high scores obtained by students in the experimental groups could be attributed to the exposure to the IBL approach. The gain in the means between post-test and pre-test in the experimental group 1 was large (24.56) and control group 1 was small (11.19), but on making a critical observation, the mean gain in the experimental group 1 was larger than in control group 1 (Table

4.9). Presenting the pre-test and post-test means of experimental group 1 and control group 1 graphically, helps visualise the mean difference within and between the two groups. The large difference in the group means is an indication that the treatment: that is, the IBL approach had a greater effect on the post-test mean score when compared to the pre-test mean score. The mean difference between experimental group 1 and control group 1 was also large (13.37), this confirms that the experimental group 1 (which was exposed to IBL after pre-test) had a higher achievement in the BSPSAT.

Table 4. 9: Pre-Test and Post-Test Means and Standard Deviations of Experimental Group 1 and Control Group 1

		PRE-TEST		**POST-TEST**		
Groups	***n***	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean Gain**
Experimental group 1	52	36.02	13.15	60.58	13.17	24.56
Control group 1	64	35.94	11.97	47.13	9.73	11.19
	Mean Difference					**13.37**

Source: Research Data, 2016 N = 220

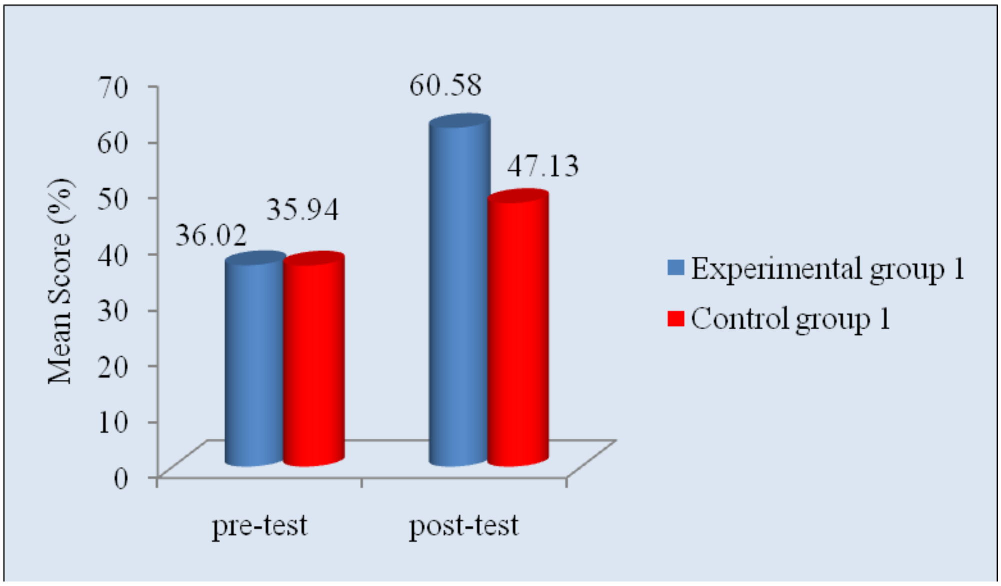


Figure 4. 3: Figure 4.4 Pre-test and Post-test Means of Experimental Group I and Control Group I

To establish whether the mean gains are significant, an independent samples *t*-test was conducted at a significance level of alpha (α) .05. The findings of this test are illustrated in table 4.10.

Table 4. 10: t-test for Equality of Post-Test and Pre-Test Means for Experimental Group 1

Variable	**Paired difference**				
	T	*df*	Sig.(2-tailed)	Mean Difference	Std Deviation
BSPSAT	9.687	51	.000	24.558	18.280

Source: Research Data, 2016 *n* = 52

The independent samples *t*-test had a *p* value of .000 as shown in Table 4.10. This *p*-value is less than the alpha value (α = .05). Based on this observation, it was decided that there is a significant difference in the post-test and pre-test mean scores in experimental group 1. Hence, it was concluded that there is evidence to show that the post-test scores were higher than the pre-test scores in experimental group 1.

Table 4. 11: *t*-Test for Equality of Post-Test and Pre-Test Means for Control Group 1

Variable	**Paired difference**				
	t	*df*	Sig. (2-tailed)	Mean Difference	Std Deviation
BSPSAT	5.978	63	.000	11.188	14.972

Source: Research Data, 2016 *n* = 64

The independent samples *t*-test had a *p* value of .000 as shown in Table 4.11. This *p* value is less than the alpha value (α = .05). Based on this observation, it can be decided that there is a significant difference in the post-test and pre-test mean scores in control group 1. Hence, it was concluded that there is evidence to show that the post-test scores were higher than the pre-test scores in control group 1. From the *t*-tests above it is observed that the mean gains in both the experimental group 1 and control group 1 are statistically different.

The first null hypothesis of the study was “There is no significant difference between mean achievement score of students’ when taught Biology using inquiry-based learning and those taught using traditional learning.” One-way Analysis of Variance (ANOVA) test was conducted to determine the significant difference between the two groups (i.e. experimental and control group). The results of the data analysis to test hypothesis 1 (H_{O1}) is presented in Table 4.12.

Table 4. 12: Analysis of Variance (ANOVA) of Post-test Scores on BSPSAT

Source of Variation	Sum of Squares	*Df*	Mean of Squares	*F*	*p* value
Between Groups	13877.691	3	4625.897	30.293	.000
Within Groups	32984.109	216	152.704		
Total	46861.800	219			

Source: Research Data, 2016 $N = 220$

Table 4.12 shows $F(3, 216) = 30.293$, $p = .000$. The p value is less than the significant level of, alpha value, .05 ($p < .05$). A decision was made to reject the null hypothesis. The implication is, there was a statistically significant difference between the means of the experimental and control group as detected by the one-way ANOVA $F(3,216) = 30.293$, $p = .000$. It was concluded there is enough evidence that the mean scores of students from the groups were not all equal (refer to Table 4.8). It was necessary to conduct a post-hoc test to establish where the difference occurred. The test was carried out using Least Significant Difference (LSD) procedure at $p < .05$ level.

Table 4. 13: Post-Hoc Comparison of the Post-test of BSPSAT Means for the Four Groups

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
Experimental Group I	Control Group I	13.452*	2.307	.000
	Experimental Group II	1.327	2.380	.578
	Control Group II	19.369*	2.473	.000
Control Group I	Experimental Group I	-13.452*	2.307	.000
	Experimental Group II	-12.125*	2.261	.000
	Control Group II	5.917*	2.360	.013
Experimental Group II	Experimental Group I	-1.327	2.380	.578
	Control Group I	12.125*	2.261	.000
	Control Group II	18.042*	2.431	.000
Control Group II	Experimental Group I	-19.369*	2.473	.000
	Control Group I	-5.917*	2.360	.013
	Experimental Group II	-18.042*	2.431	.000

* The mean difference is significant at $p < 0.05$

Source: Research Data, 2016 $N = 220$

Post-hoc comparison of the post-test shows that the mean difference between the experimental group I (group 1) and control group I (group 2) and control group 2 (group 4) were statistically significant. Experimental group 2 (group 3) also showed statistically significant difference with control group I (group 2) and control group 2 (group 4). From the study, group 1 and 3 (experimental group 1 and 2) are the groups that received treatment, the post-hoc results on comparison of means confirms that IBL had a positive effect on students achievement in BSPSAT, hence the first null hypothesis that guided the study was rejected.

4.4.3 Discussion of Findings

Inquiry-based learning is the art of developing challenging situations through observation and questioning phenomenon using explanations whereby students are actively involved in the process (Hattie, 2013). Further noting, Spronken-Smith (2010), argued that IBL is a learner-centred approach which provides a move to self-directed learning with students taking increased responsibility for their learning and the development of skills in self-reflection and an active approach to learning. This study established that the difference between the experimental groups and control groups is statistically significant on the post-test scores of BSPSAT (p value is .000, less than $\alpha = .05$) and F calculated, $F(3, 216)$ is 30.293. The findings also indicated that the students in the experimental groups achieved higher mean scores (60.58 and 59.25) in the BSPSAT than those students taught using the normal traditional learning (47.13 and 41.20). These findings support observations made by KNEC (2013), which noted that the low mean percentages recorded by candidates are attributed to: instruction that does not go beyond the classroom, but is based on mere transfer of factual information, lack of creativity for topics with abstract content, simple memorization of biological facts and failure to link them to biological processes.

The findings of this study are also consistent with those of earlier studies that have been conducted on IBL and the 5E learning cycle. A study conducted by Ajaja (2013) involving senior secondary class II (SS II) students (equivalent to Form two), from public secondary schools in the Delta state area in Nigeria, on the effects of 5E learning cycle on students' achievement in Biology, found out that the use of 5E learning cycle led to enhanced achievement in the 5E learning cycle group than those taught with the regular lecture method. Another study conducted by Khan and Iqbal (2011), involving ninth grade (equivalent of form one level) secondary school

Biology students on the effectiveness of inquiry-based teaching in the development of Science Process Skills, observed that inquiry-based teaching had a positive effect on students' development of SPS in the treatment group. The achievement of students in the treatment group was higher than that in the control group. They also established that the difference in the means between the experimental and control groups were statistically significant and was in favour of the experimental group.

In other science subjects such as Physics and Chemistry, similar findings have been observed. In Physics subject, studies have been conducted by Njoroge *et al*. (2014) involving Form two students from single sex county schools in Nyeri County, Kenya on the effects of inquiry-based teaching approach on secondary school students' achievement and motivation in Physics in the learning of the magnetic effect of an electric current in secondary Physics course. They compared students taught using inquiry-based teaching with students taught using regular/traditional teaching methods. The experimental groups in their study recorded mean scores of 22.46 and 21.70, while the control groups recorded mean scores of 15.51 and 16.70 respectively. These results showed that there was a significant difference in students achievement between the two groups, F calculated (3, 366) was 30.34, $p = .00$ at α .05 and F critical was 2.60. The finding of this study confirms the observation made by Njoroge *et al.* (2014).

In Chemistry subject, a study was carried out by Abungu *et al.* (2014) involving Form three students from Nyando sub-county of Kenya, on the effects of a Science Process Skills teaching approach on secondary school students' achievement in Chemistry. The research established that a Science Process Skills teaching approach enhanced the Science Process Skills of students in Chemistry, F calculated (3,149) was 41.53, p =

.00 at α .05 and F critical was 2.67. Using the chemistry achievement test that was administered, the study concluded that this teaching method emphasized on the use of SPS which helped the learners perform well in practical activities, hence better achievement in Chemistry than those learners exposed to the regular teaching method. Science Process Skills teaching approach is an inquiry-based teaching-learning approach. In view of this observation, this study also agrees that inquiry-based learning encourages the use of SPS, hence learners are able to acquire and develop these skills and post better performance in assessments that evaluate SPS. Other studies conducted that have supported the effectiveness of IBL in enhancing students' academic learning outcomes such as academic achievement, motivation and attitudes include Abdi (2014), Ikitde and Edet (2013), and Opara (2011).

4.5 Inquiry Based-Learning and Gender and Academic Achievement

The third objective of the study was to examine the interaction effect between IBL and gender on students' achievement in Biology subject. This was determined by administering a BSPSAT which tested on the following Science Process Skills; observing, classifying, measuring, communicating, inferring, interpreting data, controlling variables, defining operationally, hypothesizing and experimenting, predicting and creating models. Data was collected and analysed under the research question "What is the interaction effect between IBL and gender on students' achievement in Biology subject?

The performance of male and female Biology students differs at the KCSE level. Statistics indicated by KNEC show that male students have outperformed the female students over the years in Biology subject (KNEC, 2011-2016). Due to this observation, this study sought to establish the interaction effect between IBL and gender on students' achievement in the BSPSAT. Under the third objective, the factors of concern were IBL and gender and their interaction effect on learners' achievement in BSPSAT. Two-way ANOVA was used to test the effect of the IBL and gender. To conduct the two-way ANOVA test, the students were grouped into four groups on basis of the factors in question–teaching-learning method and gender (Bluman, 2012). Table 4.14 illustrates the groups. The ANOVA design used was a 2 x 2 design, since each variable consists of two levels or two different treatments (Bluman, 2012).

Table 4. 14: Groups for Teaching-Learning Method and Gender

	Gender	
	IBL	IBL
Teaching-Learning Method	Male	Female
	TL	TL
	Male	Female

The null hypothesis for the two-way ANOVA was "There is no significant interaction effect between IBL and gender on students' achievement in Biology subject". Data analysis for the two-way ANOVA is shown in Table 4.15.

Table 4. 15: Two-way ANOVA Summary for Teaching-Learning Method and Gender

Source	**Sum of Squares**	***df***	**Mean Square**	***F***	***p* value**
Teaching Method	13877.7	3	4625.9	31.5905	0.000
Gender	46.6	1	46.6	0.3180	0.573
Teaching Method*Gender	1893.7	3	631.2	4.3107	0.006
Residuals	31043.8	212	146.4		
Total	46861.8	219			

Source: Research Data, 2016 $N = 220$

A two-way ANOVA was conducted that examined the effect IBL and gender. The results established that there was a significant interaction between IBL and gender on achievement in BSPSAT i.e. $F(3, 212) = 4.3107$, $p = .006$. The results showed that the F calculated value (4.3107) is greater than the p value (.006). A decision was therefore made to reject the null hypothesis, since the interaction between IBL and gender is statistically significant. The implication of rejecting the null hypothesis means that there is an interaction effect between IBL and gender on the students' achievement in BSPSAT. Verification of this finding was done by obtaining an interaction plot for the means of the post-test scores and treatment groups. The means of the groups is shown in Table 4.16.

Table 4. 16: Post-test Means for Experimental and Control groups

	GROUP	
GENDER	**Experimental Group (EG)**	**Control Group (CG)**
Male	58.26	46.84
Female	62.03	40.71

Source: Research Data, 2016 $N = 220$

The interaction plot for the group means is shown in the graph.

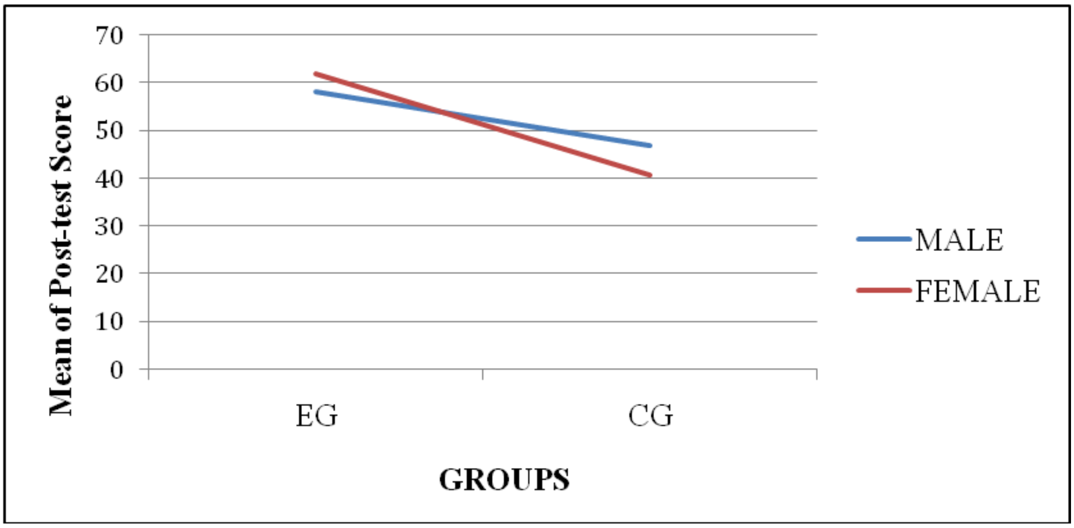


Figure 4. 4: Interaction plot for group post-test Means

The intersection of the lines implies that the interaction effect is significant (Bluman, 2012). From the graph it is observed that the line denoting the means for male students intersects with that of the female students. This is a clear indication of the statistically significant interaction effect between IBL and gender in terms of BSPSAT. Furthermore, the significance of the interaction effect proved by the *F*-calculated value is further asserted by the intersecting lines illustrated in the graph.

Since the null hypothesis for interaction effect was rejected, it was concluded that the combination of teaching-learning method and gender does affect students' achievement in the BSPSAT. From the study it is observed that the female students exposed to IBL had a higher mean in the post-test of BSPSAT while the mean of the male students exposed to TL had a higher mean in the post-test of BSPSAT. That is, female students performed better than their male counterparts when taught using IBL while male students performed better than the female students when taught using TL.

4.5.1 Discussion of Findings

This study revealed that there is a statistically significant interaction effect between IBL and gender in terms of achievement in BSPSAT. The revelation of this finding implies that the teaching method applied (IBL) does not influence achievement in BSPSAT independently, but is dependent on the gender of the students so as to bring about positive achievement in Biology subject. However, this finding is contrary to the findings established by Ajaja (2013), when he conducted a study on the effects of 5E learning cycle on students' achievement in Biology and Chemistry. In his study, he established a non significant interaction effect between the teaching method used and gender on achievement in Biology. In a comparison of the female and male students post-test mean score, the female students mean score (49.91) was higher than that of the male students (46.92). He also noted that the range in the female and male students mean score in the 5E learning cycle group was too small (2.99) to give a significant difference in the interaction effect.

Considering this study, a comparison of the post-test mean score of female and male students in the experimental group 1 (females: 63.73, males: 58.27) and experimental group 2 (females: 60.33, males: 58.24); it was observed that in both experimental groups the female students recorded higher mean scores than their male counterparts. The difference in the mean score of the female and male students in this study implies that the IBL approach favoured the female students over the male students based on the BSPSAT.

Taking onto consideration the post-test scores from the groups in the conventional teaching-learning method (TL), observations made are: the male students performed better than the female students. That is control group 1 (males: 47.57, females: 46.52) and control group 2 (males: 46.11, females: 34.90). This observation can help provide an answer as to how examination scores in Biology KCSE can be brought to parity on the basis of gender. According to the KNEC statistics (2011-2016, Appendix I) on Biology subject performance, it is indicated that male students record higher mean percentages in Biology subject compared to the female students. Another study that revealed different results from this study was done by Nwagbo and Chukelu (2011). The study sought to determine the effects of Biology practical activities on students' Science Process Skills acquisition in the topic of nutrition at SS I (equivalent to form one level). This study was conducted in Abuja, Nigeria. The study established that there was no significant interaction effect between teaching method and gender. The findings of Nwagbo and Chukelu (2011) therefore do not concur with the findings of this study. The next chapter presents summary of findings, conclusion and recommendation.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction of the Chapter

This chapter focused on the summary, conclusion and recommendation for action as well as suggestions for future research as relates to the study. The main purpose of this study was to determine the extent to which inquiry-based instruction affects the performance of SPS in terms of acquisition and application of these skills to achieve in a test among form three students who studied Biology in Wareng sub-county, Uasin-Gishu County, Kenya. This study comprised of four chapters which covered the following themes the background of the study, literature reviewed, research design and methodology, data analysis, presentation, interpretation and discussion.

5.2 Summary of Study

This was covered under the three objectives of the study.

5.2.1 Inquiry-Based Learning and Level of Acquisition of Science Process Skills

The first objective of the study was to determine the influence of inquiry-based learning on students' level of acquisition of Science Process Skills in Biology subject. The study found out that inquiry-based learning (IBL) had a positive influence on the acquisition levels of Science Process Skills in Biology subject among students in the experimental (treatment) group. The study also established that classifying (80.6%), observing (76.9%), experimenting (75%), predicting (73.2%) and measuring Science Process Skills were the skills that had high levels of acquisition when using inquiry-based learning approach. On the other hand, integrated skills such as formulation of hypotheses (54.6%), defining operationally (55.6%) and controlling variables (59.3%) had relatively lower levels of acquisition when compared to the basic Science Process Skills. These findings confirm those of earlier studies regarding the levels of acquisition of Science Process Skills (Ajaja, 2013; Khan & Iqbal, 2011).

5.2.2 Inquiry-Based Learning and Science Process Skills achievement

The second objective was to establish the difference between students' achievement when taught using IBL approach and TL approach in Biology subject. It was established that there was a significant difference between students' achievement in BSPSAT in the experimental group (IBL approach) and control group (TL approach). The mean score of the students in the experimental group was higher than that of students in the control group. These findings revealed information that is in agreement with previous studies that IBL yields positive learning outcomes in students (Abdi, 2014; Abungu, et al., 2014; Khan & Iqbal, 2011; Njoroge, *et al.*, 2014).

5.2.3 Inquiry Based-Learning and Gender and Achievement

The third objective was to examine the interaction effect between IBL and gender on students' achievement in Biology subject. The study established that there was significant interaction effect between teaching method and gender in students' achievement in BSPSAT. The findings revealed that the female students in the experimental group performed better (had a higher mean score) than the male students in the same group, while male students in the control group had a slightly higher mean score than female students in the same group. The findings contradict the current situation of achievement in Biology, where female students have consistently recorded lower mean percentages compared to the male students over the years at the KCSE level (KNEC, 2011-2016). The findings also contradict previous studies that looked into the interaction effect of teaching method and gender on students' achievement, these studies established that there was no significant interaction effect between teaching methods used and gender on students' achievement (Ajaja, 2013; Mohamad & Ong, 2013; Nwagbo & Chukelu, 2011).

5.3 Conclusions of the Study

This study concludes that inquiry-based learning in Biology is an effective teaching-learning method on the acquisition of Science Process Skills. Inquiry-based learning leads to a higher level of Science Process Skill acquisition favouring basic Science Process Skills in comparison to integrated Science Process Skills. As much as the acquisition levels of the integrated Science Process Skills were lower than the basic Science Process Skills, IBL approach recorded above average mean values for these skills when it was used to teach students of Biology in the Study. Hence IBL can be considered to be an effective method that can bring about a positive learning outcome on the level of acquisition of Science Process Skills in Biology subject at secondary school level. Teaching through IBL is important in the acquisition, development and achievement of Science Process Skills among secondary school Biology students

Inquiry-based learning manifested a significant difference in students' achievement in the BSPSAT in the ecology topic compared to those exposed to conventional traditional learning method. Inquiry-based learning helped students to acquire and develop Science Process Skills through emphasizing learning by participation, thus allowed students to apply these Science Process Skills when they answered questions in the BSPSAT. The acquisition of Science Process Skills enhances the ability of students to achieve highly in tests. This study concluded that inquiry-based learning is more effective on the acquisition of Science Process Skills than the traditional learning method. With regard to achievement in BSPSAT, inquiry-based learning leads to higher gains in the application of Science Process Skills. Inquiry-based learning provided an environment that encouraged the learners to become active participants as they took responsibility for their learning. The teacher's role was that of a facilitator at the same time allowing for mutual enjoyment between teachers and students (Spronken-Smith, 2010).

In addition, a significant interaction effect between IBL and gender in students' achievement was observed in the study. Achievement of student scores in BSPSAT was due to the effect of IBL and the gender of students. This was indicated by the significant difference observed in the achievement scores among students taught using IBL and TL. Female students scored highly in the experimental group, while male students scored highly in the control group. Inquiry-Based Learning favoured female students, in the sense that they posted higher achievement than the male students. In the same vein, IBL can be considered as a preferred teaching and learning method to help improve the low scores of female students in Biology subject, making it possible for them to be at par with their male counterparts. Since IBL recorded mean gains in the experimental group, the teaching approach can also be used to help both female and male students to better their scores, thus recording higher achievement.

5.4 Recommendations of the Study

In relation to the conclusions of the study, it was recommended that:

1. Inquiry-Based Learning has the potential to help students acquire and develop Science Process Skills, therefore it should be enhanced as a teaching-learning method in secondary schools as a means of helping learners gain skills that

will help them in their day to day life, particularly in the fulfillment of Vision 2030, which is the government's flagship to being industrialized by the year 2030.

2. Inquiry-Based Learning helps students to attain higher achievement in Biology subject, therefore teachers should be encouraged to use IBL in the teaching of Biology so as to help students to actively participate during the teaching and learning process. That is self reflect and develop the necessary skills to answer questions correctly. This will help in the realization of better performance and higher mean percentages in the KCSE Biology examination. Inquiry-Based Learning should be used as an instructional approach that will help the Ministry of Education Science and Technology (MoEST) to achieve it intention of ensuring learners acquire, develop and apply Science Process Skills to improve their performance in both theory and practical examinations in Biology.
3. Inquiry-based learning should be applied to fulfill the deliberate effort of the MoEST to bridge the gap between male and female students' performance in Biology, especially at KCSE level to achieve equal representation in Biology and in Biology oriented career opportunities.

5.5 Suggestions for Further Research

The study has established some knowledge gaps that require further studies.

1. There is need for other researchers to carry out a study on the effectiveness of other teaching methods that are student-centred which employ the process of inquiry such as project work and their effect on the application of Science Process Skills.

2. This study focused on the acquisition of SPS and achievement in ecology topic at Form three level. Similar studies using IBL can be conducted with focus on different topics from the form three Biology syllabus such as classification. Research can also be conducted using different class levels such as form one and Form two.
3. Similar studies can also be conducted at higher education levels such as colleges and universities to establish the effect of IBL on SPS among students at higher levels. This will help to draw a comparison to determine the degree of effectiveness as regards IBL and education level.
4. The study was geographically limited to Wareng Sub-County; it is therefore necessary to carry out replicated studies in wider geographical areas (counties) or in other sub-counties.
5. This study established an interaction effect between the IBL and gender and academic achievement. Therefore it is important to conduct studies to establish the effect of IBL and gender of students' on performance in Biology subject at national and/or school level(s).

5.6 Summary of chapter

This chapter covered the summary, conclusion and recommendation for action as well as suggestions for future research as relates to the study.

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APPENDICES

APPENDIX I

CANDIDATES OVERALL PERFORMANCE IN THE YEARS

2010-2015

YEAR	MEAN PERCENTAGE (%)		
	FEMALES	MALES	OVERALL
2010	26.99	31.24	29.23
2011	30.07	34.53	32.44
2012	24.36	27.86	26.21
2013	30.15	32.99	31.63
2014	29.84	33.71	31.83
2015	32.87	36.64	34.80

Source: KNEC (2011-2016)

APPENDIX II

LOCATION OF WARENG SUB-COUNTY IN UASIN-GISHU COUNTY

Source: Source: Google Maps

APPENDIX III

BIOLOGY SCIENCE PROCESS SKILL ACHIEVEMENT TEST (BSPSAT)

Gender______________________ **Date______________________**

INSTRUCTIONS

1. Write your gender and date in the spaces provided
2. Read the questions carefully before answering
3. Write your answer in the spaces provided on the question paper.
4. Return the question paper after completion of the exercise.

QUESTIONS

1. Which of the following parameters is not likely to be observed when studying abiotic factors in an ecosystem? Salinity, mimicry, atmospheric pressure, turbidity and rainfall. (1 mark)

____

2. Cheetahs are organisms that prey on different organisms such as buffaloes, deer and wildebeests. An ecologist, studying a grassland ecosystem, carried out an experiment that required the removal of the cheetahs from the ecosystem.

a) State one event that is likely to occur in this grassland ecosystem? (1 mark)

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____

____

b) State a suitable hypothesis for this study. (2 marks)

c) What should the ecologist do to ensure that there is no competition in this ecosystem? (2 marks)

d) Draw an Illustration to show the relationships between producers and consumers in the above ecosystem. (1 mark)

3. Form three students of Kenya secondary school conducted a field study on edaphic factors in a terrestrial ecosystem. They collected different soil samples. Briefly describe how they would measure water soil content of the soil samples in the laboratory. (3mks)

4. An empty tin of jam was placed in the school compound of school A and left for seven days. After 3 days, form three students of school A discovered there were fruit flies in the tin. The flies were counted, 16 flies were recorded and the tin was covered. After another 3 days they counted 9 flies. Explain what could have happened in the tin to reduce the number of fruit flies? (4 marks)

5. Form three students in turbo secondary school wanted to establish the biomass of black jack weeds in their school garden. Briefly describe an experiment that they can use to estimate the biomass of the black jack weed? (4 marks)

6. Students from Nakuru School carried out an ecological study in Lake Nakuru national Park. They recorded each type of animal they saw. The following animals were on their list: Lion, cheetah, gazelle, hyena, rat, zebra, monkey, weaverbird, and grasshoppers.

   a) Draw a possible food web to illustrate the feeding relationships among these animals. (2 marks)

b) Suppose the vegetation in the park is destroyed by fire, what would happen to the organisms in the park? (2 marks)

7. Some students planted beans in the school garden. After 4 weeks they uprooted some of the bean plants and observed their roots. They noted that the roots had root nodules. Explain the relationship between root nodules and the bean plants. (3 marks)

8. The photograph below shows an interaction of organisms in a certain ecosystem. Study it and answer the questions that follow.

a) Name the type of ecosystem shown in the photograph. (1 mark)

____

b) What feeding relationship is exhibited by the animals shown in the photograph? (1 mark)

____

c) Name the organism that occupies the highest feeding level (1 mark).

9. Students in form three west went to the school's nature reserve and wanted to measure the environmental factors in the reserve.

a) How would they measure the environmental temperature? (2 mark)

____

____

____

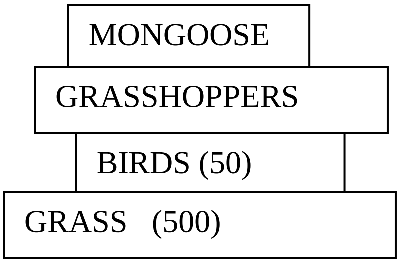
____

b) Which the unit of measurement did the students use to record the temperature reading? (1 mark)

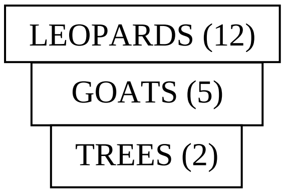
---

10. a) Which pyramid of numbers illustrates a balanced ecosystem? (1 mark)

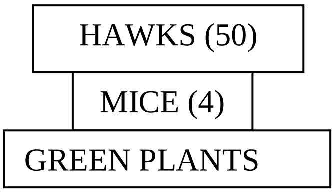
A)



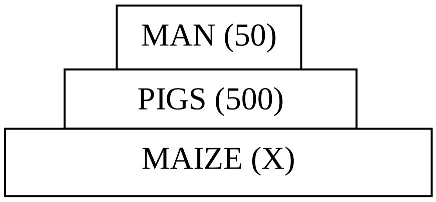
B)



C)



D)



Pyramid

---

c) Explain your answer in 10 (a) above (3 marks).

d) Using a scale of 1cm = 50 organisms, calculate the number of maize plants (X) represented by the bar in pyramid D above. (3 marks).

THANK YOU FOR YOUR TIME TO SIT FOR THIS TEST

APPENDIX IV

TABLE OF SPECIFICATION OF SKILLS MEASURED IN BSPSAT

Question / Skill	1	2	3	4	5	6	7	8	9	10	**Total score**
Classifying	1							1			**2**
Predicting		1				2					**3**
Hypothesising		2									**2**
Inferring				3							**3**
Experimenting					4						**4**
Observing								2		1	**3**
Interpreting Data										3	**3**
Controlling Variables		2									**2**
Defining Operationally			3								**3**
Measuring									3	1	**4**
Creating Models		1				2					**3**
Communicating							4				**4**
TOTAL	**1**	**6**	**3**	**3**	**4**	**4**	**4**	**3**	**3**	**4**	**35**

APPENDIX V

RUBRIC FOR BSPSAT

1. Determines ability of learner to *group* environmental factors in question into abiotic and biotic factors. This guides them to identify the factor that is odd.
2. a). Ability to state the *future expectation* after cheetahs are removed. They are required to group the organism on basis of feeding level then remove the group that has been removed so as to state the effect. SKILL- Predicting

   b). Ability to state the *expected outcome or observation* from the experiment in question. SKILL- Formulating Hypothesis

   c). Ability to *manipulate factors* in the ecosystem in order to achieve expected results SKILL- Controlling Variables

   d). *Draw* a food chain to show how nutrients will be transferred from one group of organisms to another. SKILL-Creating models
3. Describe or state *how to measure the variable* in question (Soil water content). SKILL- Defining operationally
4. Make an *explanation of observations* and giving reasons for the observation. SKILL- Inferring
5. Explaining *procedures to be followed to obtain verifiable results*. SKILL- Experimenting.
6. a) *Draw* a food web to show how organisms depend on each other. SKILL- Creating models

   b) Ability to state the *future expectation* after vegetation is removed. Require knowledge on nutritional dependency. SKILL- Predicting

7. Use *words, symbols, or objects to describe* an event or object. SKILL- Communicating
8. a) Ability to *perceive* what the photograph is illustrating using *eyes* and relate features the correct ecosystem. SKILL- Observing

   b) Ability to *perceive* how the organisms are interacting in the photograph using *eyes* and relate to biotic relationships. SKILL- Observing

   c) Ability to *categorise* the organisms into their feeding levels. SKILL- Classifying
9. Ability to *use standard form of instruments and units* in measurement. SKILL- Measuring.
10. a) Ability to *perceive* what the graphs are illustrating using *eyes* and relate to knowledge on biological pyramids. SKILL- Observing

    b) Ability to arrive at an *explanation* by critically observing the given *data*. SKILL- Interpreting Data

    c) Ability to *use an instrument* to obtain measurements in the correct unit and perform calculations to state the number of organisms in question. SKILL- Measuring.

APPENDIX VI

BIOLOGY SCIENCE PROCESS SKILLS QUESTIONNAIRE (BSPSQ)

This questionnaire is part of my phD study in Science Education (Biology) that I am undertaking at University of Eldoret. One of my objectives is to study secondary school students' achievement of science process skills. With regard to the above, this questionnaire is meant to examine you on how the method used to teach affects your level of acquisition of science process skills. The information that will be gathered from your response will help in providing useful data for my study. Do not include your name and the name of your school. I would greatly appreciate you taking time to complete for this questionnaire.

GENERAL INFORMATION

Read the following questions carefully and tick the appropriate response for each question.

Please tick (√) in the appropriate bracket

PART 1: DEMOGRAPHIC DATA

1. Gender: 1. Male [ ]   2. Female [ ]

2. Age   1. 15-16 [ ]   2. 17-18 [ ]   3.More than 18 [ ]

Read carefully the following statements and rate them as: -

1. *S.D-Strongly Disagree; 2. D- Disagree; 3. U-Undecided; 4. A-Agree and 5. S.A-Strongly Agree*

PART II: LEVEL OF ACQUISITION OF BIOLOGY SCIENCE PROCESS SKILLS CONCEPTS

4. Read the following statements carefully and rate them on a scale of 1-5: 1. Strongly disagree, 2. Disagree, 3. Undecided, 4. Agree and 5. Strongly Agree. To what extent does the teaching and learning approach used affect your level of acquisition of Science Process Skills in Biology subject? Please place a tick [√] in the corresponding box of the statement you think is the most preferred response.

LEVEL OF ACQUISITION OF SCIENCE PROCESS SKILLS CONCEPTS	**1**	**2**	**3**	**4**	**5**
A. BASIC SCIENCE PROCESS SKILLS	**(SD)**	**(D)**	**(U)**	**(A)**	**(SD)**
1. Helps me develop my ability to observe things critically					
2. Helps me to arrange biological information in an orderly and organised manner					
3. I can accurately measure distances in the units given of objects and drawings					
4. Helps me to use words, drawings and symbols to describe observations made when conducting experiments					
5. Helps me make conclusions/inferences from information recorded during experiments					
6. Helps me to use prior knowledge to obtain data about an object or an event's future state					

B. INTEGRATED SCIENCE PROCESS SKILLS	(SD)	(D)	(U)	(A)	(SD)
1. Helps me to interpret data					
2. Helps me to control variables when carrying out experiments					
3. Helps me develops my ability to measure a variable in an experiment					
4. Helps me to formulate aims or hypotheses of experiments I design					
5. Helps me to conduct experiments and obtain the required information successfully					
6. Helps me to display experimental or observational data in different forms using graphs, diagrams and tables					

APPENDIX VII

BIOLOGY SCIENCE PROCESS SKILLS OBSERVATION CHECK LIST

GROUP__________________________ **DATE**_____________________

SPS	DESCRIPTION	TALLY
Observing	Does the learner use five senses and words to describe objects and events?	
Classifying	Does the learner determine notable similarities and differences between objects and events?	
Measuring	Does the learner use appropriately measuring apparatus?	
Communicating	Does the learner use words, drawings and symbols to describe objects and events?	
Inferring	Does the learner make explanations of observations, objects, data or substances in quantitative form?	
Interpreting data	Does the learner arrive at explanations, inferences or hypothesis from data that has be graphed or tabulated?	
Controlling variables	Does the learner identify, keep constant and manipulate variables during experiments?	
Defining operationally	Does the learner state how to measure a variable in an experiment?	
Hypothesising	Does the learner state expected outcomes of an experiment?	
Experimenting	Does the learner test hypotheses through controlling variables in an experiment?	
Predicting	Does the learner state the outcome of a future event using previous observations?	
Creating models	Does the learner display information using graphs, diagrams and charts?	

APPENDIX VIII

TEACHER'S GUIDE FOR IBL USING 5E LEARNING MODEL

Instructions

i) Use the following procedure to teach the ecology topic.

ii) State the lesson objectives to the learners at the beginning of the lesson.

iii) Monitor students as they work to provide corrective feedback as necessary and assess the performance of different groups in determining whether the students are ready for the next instruction.

LESSON 1

Class Discussion

TOPIC: Ecology

Subtopic: Concepts of Ecology

Time: 40 minutes

Objectives: By the end of the lesson the learners should be able to:

i) Define the term Ecology

ii) State the concepts of ecology.

Teacher grouped the learners into small groups of 8-9 students

Teacher guided the learners through the phases of 5E learning model.

ENGAGEMENT

Teacher asked the students to discuss the following questions in their groups

1. Name the branches of Biology

2. From the answers provided in (1) above, which branch deals with the living organisms external surrounding?

After discussing the groups presented their answers.

This stage allowed the teacher to determine the learners' prior knowledge.

EXPLORATION

The teacher asked the students are to search for the meaning of terms used in ecology.

Autecology, synecology, habitat, ecological niche, population, community, ecosystem, biosphere, biomass and carrying capacity.

EXPLANATION

The teacher engaged the class in a discussion (in their groups)

The teacher asked the learners to answer the following questions in their groups

1. What is the difference between the following terms:
   - i) Autecology and synecology
   - ii) Habitat and ecological niche
   - iii) Population and community
   - iv) Ecosystem and biosphere
   - v) Biomass and carrying capacity

Learners presented the answers to the questions as the teacher listened.

The teacher corrected the learners where answers were wrong and introduced relevant vocabulary or terminologies so as to provide correct answers.

The teacher also asked students questions on the terminologies introduced to ascertain that learners understood the teachers' explanation

ELABORATION

The teacher presented photographs of animals in different environments (terrestrial and acquatic).

Learners *observed* the photographs (A and B) and answered the following questions

1. What is the ecological niche of earthworms in photograph A?
2. a) Which photograph illustrates the concept of synecology?

   b) Explain your answer in 2(a) above.

EVALUATION

To demonstrate an understanding of knowledge of the concept and skills, the teacher evaluated students own progress and knowledge by asking the following questions.

1. Define ecology and ecosystem.
2. Give examples of ecosystems
3. Distinguish between biomass and carrying capacity

LESSON 2

TOPIC: Ecology

Subtopic: Concepts of Ecosystem

Time: 80 minutes

Objective: By the end of the lesson the learners should be able to:

i) Investigate the various concepts of ecology. That is:

- Habitat
- Ecological niche
- population
- Community

Teacher grouped the learners into small groups of 8-9 students

The learners are allocated various stations in the school (school farm/ garden, flower beds, forested zone, playing fields, grassland, trees).

Teacher guided the learners through the phases of 5E learning model.

ENGAGEMENT

Teacher asked the learners the following questions.

1. What is a habitat of an organism?
2. Define the term ecological niche.
3. Distinguish between a population and a community

   After discussing the groups presented their answers.

This stage allowed the teacher to determine the learners' prior knowledge.

EXPLORATION

Learners worked in groups.

Teacher asked the students to look for different organisms from the allocated stations.

Learners were to find out the following for each of the organisms collected.

1. Identify the habitat- what is the exact place an organism is found?
2. Identify the ecological niche.
3. What is the estimate of the number of organisms in your station?

EXPLANATION

The teacher engaged the groups in a discussion by allowing the learners to use their results to answer the following questions.

1. What is the role of each organism to its surrounding?
2. What are the factors in organisms surrounding that attract it to this specific area?
3. What influences the numbers of organisms in a place?
4. Which organisms are abundant in the area studied? Explain.

Learners answered the questions as the teacher listened to them.

The teacher corrected the learners where explanations were wrong.

ELABORATION

The groups present their results to allow for comparison of the various stations studied.

The following questions guided the learners in the discussion.

1. How does the habitat of an organism relate to its role?- Organisms found where they have a part to play e.g. termites found on dead wood , feed on it to breakdown the nutrients in it .
2. What factors favour the existence of organisms in their habitats.-suitable conditions for growth and reproduction- such as food and space?

EVALUATION

To demonstrate an understanding of knowledge of the concept and skills, the teacher evaluated students own progress and knowledge by asking the following questions.

1. Did the organisms exist as a population or a community?
2. Give reasons for your answer.

LESSON 3

Practical Lesson

TOPIC: Ecology

Subtopic: Factors in an Ecosystem

Time: 80 minutes

Objective: By the end of the lesson the learners should be able to:

i) Measure the following factors in the ecosystem they are studying:

- pH
- Temperature
- Humidity
- Wind direction
- Soil water content

Teacher grouped the learners into small groups of 8-9 students

The learners are allocated various stations in the school (school farm, pond/ water logged area, forested zone, playing fields, grassland, trees) .

Teacher guided the learners through the phases of 5E learning model.

ENGAGEMENT

Teacher asked the students to discuss the following questions in their groups

1. What constitutes an ecosystem?
2. What are the physical/environmental factors

After discussing the groups presented their answers.

This stage allowed the teacher to determine the learners' prior knowledge.

EXPLORATION

The teacher provides the students with the following materials:

Test tubes, BDH universal indicator solution or paper, white tiles, Barium sulphate, glass rods, pH colour charts, spatula, droppers, distilled water, specimen bottles, weighing balance, means of heating, beakers, desiccators, cobalt chloride paper, thermometer, wind vane, hygrometer and forceps.

Students were to use the provided materials to measure abiotic factors in a number of specified areas and work out an estimate of the whole ecosystem.

They were to discuss and decide which requirements would be used to measure which environmental factor.

They were also to discuss and decide the procedures that would give them the required results.

EXPLANATION

The teacher engaged the groups in a discussion by allowing the learners to use their results to answer the following questions.

1. What steps did you follow to measure the environmental factors you have measured?
2. What readings (values) did you establish for the factors you measured?
3. Were the readings the same at all areas?

Learners explain the procedures they followed as the teacher listens.

The teacher corrected the learners where procedures were wrong and asked them to repeat the activities.

ELABORATION

The groups present their results to allow for comparison of the various ecosystems studied.

Students answer the following questions to enhance their understanding of the concepts.

1. Do the abiotic factors that you have measured change from one area to another?
2. Are the levels the same in any one day?
3. What is the pH of your soil sample?

4. Is the soil sample acidic or alkaline?
5. How do you compare the results of the habitats?

EVALUATION

To demonstrate an understanding of knowledge of the concept and skills, the teacher evaluated students own progress and knowledge by asking the following questions.

Based on your findings, how is the distribution of living organisms affected by environmental factors.

APPENDIX IX

TEACHER'S GUIDE FOR TL USING LECTURE

LESSON 1

Class Discussion

TOPIC: Ecology

Subtopic: Concepts of Ecology Time: 40 minutes

Objective: By the end of the lesson the learners should be able to:

i) Define the term Ecology

ii) State the concepts of ecology.

INTRODUCTION (5 MINUTES)

The teacher introduces the lesson by relating current topic (ecology) to introduction of biology (branches of biology) specifically ecology.

Learners asked to (i) define ecology.

(ii) Name the surroundings of living organisms

LESSON DEVELOPMENT (30 MINUTES)

Teacher defines sub types of ecology – autecology and synecology.

Teacher discusses with learners the concepts of ecology by stating the terms and explaining their meaning-habitat, ecological niche, population, community, ecosystem, biosphere, biomass and carrying capacity.

Learners listen to teachers' explanation and ask questions if explanation is not clear.

Teacher also does formative checks by asking learners questions so as to determine their knowledge understanding.

Learners take down notes as teacher explains the concepts.

CONCLUSION (5 mins)

Learners recall the meaning of concepts of ecology by answering the following questions.

1. What is ecology?
2. Distinguish the following terms:
    a) Population and community
    b) Habitat and niche
    c) Biomass and carrying capacity
3. Give examples of ecosystems

    Further reading- Factors in an ecosystem

LESSON 2

Practical Lesson

TOPIC: Ecology

Subtopic: Concepts of Ecology   Time: 80 minutes

Objective: By the end of the lesson the learners should be able to:

i) Investigate the various concepts of ecology. That is:

- Habitat
- Ecological niche
- population

- Community

INTRODUCTION (10 MINUTES)

The teacher introduces the lesson by relating lesson to previous lesson –concepts of ecology.

Learners name the concepts of ecology.

LESSON DEVELOPMENT (60 MINUTES)

Learners work in groups to conduct practical activities.

Teacher provides learners with procedures on how to investigate various concepts of ecology.

Learners follow procedures to identify concepts of ecology.

Learners record their observations.

Learners present the observations

Teacher asks learners to answer the following questions?

1. What is the role of each organism to its surrounding?
2. What are the factors in organisms surrounding that attract it to this specific area?
3. What influences the numbers of organisms in a place?
4. Which organisms are abundant in the area studied? Explain.

CONCLUSION (10 MINUTES)

Lesson is recapped by asking learners the following questions.

1. What is the difference between a habitat and ecological niche?
2. Distinguish between a population and community.

Assignment

Read on abiotic factors in an ecosystem

LESSON 3

Theory Lesson

TOPIC: Ecology

Subtopic: Factors in an ecosystem Time: 80 minutes

Objective: By the end of the lesson the learners should be able to:

(i) Name environmental factors in an ecosystem.

(ii) Explain abiotic factors in an ecosystem .

INTRODUCTION (10 MINUTES)

The teacher introduces the lesson by asking learners to name the environmental factors.

Teacher briefly explains how environmental factors affect the type of organism and their distribution.

LESSON DEVELOPMENT (60 MINUTES)

Teacher- learner discussion on abiotic factors of an ecosystem (light, temperature, atmospheric pressure, salinity, humidity, rainfall, pH and wind) by considering the following:

- Importance of factor to living things
- Instrument used to measure the abiotic factor

Learners listen to teachers' explanation and ask questions if explanation is not clear.

Teacher also does formative checks by asking learners questions so as to determine their knowledge understanding.

Learners take down notes as teacher explains.

CONCLUSION (10 MINUTES)

Lesson is recapped by asking learners the following questions.

1. What is the main source of light in an ecosystem?
2. How does temperature affect the distribution of organisms in an ecosystem?
3. How does salinity affect the distribution of aquatic organisms?

Assignment

Read on biotic factors of an ecosystem.

APPENDIX X

LETTER FOR RESEARCH AUTHORIZATION

FROM NACOSTI

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471, 2241349,3310571,2219420
Fax:+254-20-318245,318249
Email:dg@nacosti.go.ke
Website: www.nacosti.go.ke
when replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No.

NACOSTI/P/16/59007/10845

Date:

11th May, 2016

Joy Mukhwana Wabuke
University of Eldoret
P.O. Box 1125-30100
ELDORET.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Effects of inquiry-based learning on biology students' science process skills in Wareng Sub County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Uasin Gishu County** for the period ending **10th May, 2017.**

You are advised to report to **the County Commissioner and the County Director of Education, Uasin Gishu County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Uasin Gishu County.

The County Director of Education
Uasin Gishu County.

COUNTY COMMISSIONER
UASIN GISHU COUNTY
OK
20/5/16

National Commission for Science, Technology and Innovation is ISO 9001: 2008 Certified

APPENDIX XI

RESEARCH PERMIT

THIS IS TO CERTIFY THAT:
MS. JOY MUKHWANA WABUKE
of UNIVERSITY OF ELDORET, 0-30100
ELDORET,has been permitted to conduct
research in *Uasin-Gishu County*

Permit No : NACOSTI/P/16/59007/10845
Date Of Issue : 11th May,2016
Fee Recieved :Ksh 2000

on the topic: *EFFECTS OF INQUIRY-BASED LEARNING ON BIOLOGY STUDENTS SCIENCE PROCESS SKILLS IN WARENG SUBCOUNTY, KENYA*

for the period ending:
10th May,2017

Applicant's Signature

Director General
National Commission for Science, Technology & Innovation

CONDITIONS

1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit
2. Government Officers will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two(2) hard copies and one(1) soft copy of your final report.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice

REPUBLIC OF KENYA

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No. A 9131

CONDITIONS: see back page

APPENDIX XII

LETTER OF RESEARCH AUTHORIZATION FROM COUNTY DIRECTOR OF EDUCATION

K0PO

REPUBLIC OF KENYA

HARAMBEE

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY
STATE DEPARTMENT OF EDUCATION

Telegrams: **"EDUCATION",** Eldoret
Telephone: **053-2063342** or **2031421/2**
Mobile : **0719 12 72 12/0732 260 280**
Email: cdeuasingishucounty@yahoo.com
: cdeuasingishucounty@gmail.com
When replying please quote:

Office of The County Director of Education,
Uasin Gishu County,
P.O. Box 9843-30100,
ELDORET.

Ref: No. MOEST/UGC/TRN/9/Vol II/175

20th May , 2016

Joy Mukhwana Wabuke
University of Eldoret
P.O Box 1125 - 30100
ELDORET.

RE: RESEARCH AUTHORIZATION

This office has received a letter requesting for an authority to allow you carry out research on **"*Effects of inquiry – based learning on biology students' science process skills in Wareng Sub – County*** Within Uasin Gishu County**".**

We wish to inform you that the request has been granted for a period ending **10th May, 2017.** The authorities concerned are therefore requested to give you maximum support.

We take this opportunity to wish you well during this research.

For THE COUNTY DIRECTOR OF EDUCATION
UASIN-GISHU COUNTY
TEL: 053-2063342/0719127212
P. O. Box 9843-30100,
ELDORET.

OTIENO .C. O.
For: County Director of Education
UASIN GISHU.