EFFECT OF DISCOVERY TEACHING APPROACH ON SCIENTIFIC CREATIVITY AMONGST STUDENTS OF CHEMISTRY IN PUBLIC SECONDARY SCHOOLS IN IMENTI NORTH SUB-COUNTY, KENYA.

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A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Award of the Degree of Master of Education in Science Education of Chuka University

CHUKA UNIVERSITY

SEPTEMBER, 2019

DECLARATION AND RECOMMENDATIONS

Declaration

This thesis is my original work and has not been presented for an award of a diploma or conferment of a degree in any other university or institution

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Recommendations

This thesis has been examined, passed and submitted with our approval as University Supervisors.

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DEDICATION

I dedicate this Thesis to my beloved wife Serah Wanja, children Alicia Mwende and Philbert Mugambi and my parents, Elizabeth Karei and Grassiano Kirianki.

ACKNOWLEDGEMENT

I thank the almighty God for His guidance, protection and provision throughout the study period. I sincerely thank the management of Chuka University for granting me the opportunity to study this Master of Education degree in Science Education. It could not have been easy without the assistance of my able supervisors Dr. Mercy Wanja and Dr. Denis Kirimi. I also appreciate National Council for Science Technology and Innovation (NACOSTI) for permitting me to proceed with the research work, the county commissioner, Meru County for allowing me partake the study in the area of his jurisdiction and the ministry of education for letting me conduct the study in the public secondary schools. I am also grateful to my respondents for providing me with the information that I needed for the study and the teachers who administered the tests, marked and scored them making it possible for me to get the data.

Besides, I acknowledge my family; first my wife Serah Wanja, children Alicia Mwende and Philbert Mugambi for their tireless support during the study period. I also appreciate my classmates at Chuka University for their unfaltering motivation and encouragement to move on. I thank the principals of the public secondary schools for cooperating and allowing the schools to participate in the study. Special regards to my colleagues at Kaaga Girls' High School and friends for their encouragement and Support during the period. May God bless all those who have contributed to my success in this course.

ABSTRACT

The Chemistry curriculum in Kenya anticipates production of learners who possess scientific creativity abilities of sensitivity, Recognition and Flexibility to solve day to day life. Approaches of teaching chemistry ought to promote Scientific Creativity amongst Chemistry students. In spite of this, level of Scientific Creativity amongst secondary school Chemistry students has remained low. This is attributable to the teaching approaches in use. The current study investigated the effect of Discovery Teaching Approach on Scientific Creativity amongst students of chemistry in Public Secondary schools in Imenti North Sub-county. The study is based on Gardiner's Theory of Multiple Intelligence and Okere's model Scientific Creativity. The study used Solomon-Four Non-Equivalent Control Group Design. The study was conducted in four County Girls' Only Public Secondary Schools. Purposive sampling technique was used to select the participating schools. The target population was all the students in Public Secondary Schools in Imenti North Sub-County. A sample of 186 Form Three students participated in the study. Chemistry Creativity Test (CCT) and Chemistry Class Creativity Observation Schedule (CCCOS) were the research instruments. Validity of the tools was ascertained by high school chemistry teachers who are examiners with the Kenya National Examinations Council (KNEC) and Chuka University lecturers in the Department of Education who are experts. Piloting of the tools was done in Public Secondary Schools of similar characteristics in the neighboring Imenti South Sub-County. Kuder-Richardson Formula (KR-21) was used to determine the reliability of the instruments by use of the formula [n/n-1)*[1-(M*(n-M)/(n*Var))]. The average reliability coefficient of 0.80 was obtained for the two instruments. Descriptive and inferential statistics were used for data analysis. The objectives of the study were to determine the effect of Discovery Teaching Approach on students' Sensitivity to chemistry problems, Recognition of relationships and Flexibility in reasoning when solving Chemistry problems. Three null hypotheses were generated and tested at α=0.05 level of significance. Data was analyzed using Statistical Package for Social Sciences (SPSS) computer software version 22. The results showed that there was a significant difference in Scientific Creativity when Discovery Teaching Approach was used as compared to Traditional Teaching Approaches. The study concluded that Discovery Teaching Approach improved Scientific Creativity in Chemistry amongst secondary school students. The findings of the study would be significant to the curriculum developers at Kenya Institute of Curriculum Development (KICD) and the teachers on the approaches to use when implementing the chemistry curriculum. They will also be useful to universities in planning teacher training curriculum and form basis for further research in teaching approaches that enhance scientific creativity amongst learners in other subjects in secondary school science curriculum.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
CCCOS	Chemistry Creativity Class Observation Schedule
CCT	Chemistry Creativity Test
CEMASTEA	Centre for Mathematics Science and Technology Education in Africa
DTA	Discovery Teaching Approach
IBL	Inquiry Based Learning
KICD	Kenya Institute of Curriculum Development
KIE	Kenya Institute of Education
KLB	Kenya Literature Bureau
KNEC	Kenya National Examinations Council
MOEST	Ministry of Education Science and Technology
PBL	Problem Based Learning/Project Based Learning
SMASSE	Strengthening of Mathematics and Science in Secondary Education
TTA	Traditional Teaching Approaches

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Science education may be defined as the study of inter-relationships between science as a discipline and the application of educational principles to its understanding, teaching and learning (Chioma, 2015). In secondary schools, science education involves the teaching of Biology, Physics and Chemistry in accordance to educational principles. Science education consists of three areas namely, learning science, learning about science and doing science. Doing science involves engaging in developing expertise in scientific inquiry and problem solving which promotes development of mental skills and abilities (Hudson, 2005). Science education can be taught at different schooling levels; primary, secondary, post-secondary and adult levels (Kola, 2013).

Science education provides human resource development for various countries. This is because science education is related to the enhancement of important aspects of development such as health, food, agriculture, industry and technology (Mitchell, 2012; King, 2011). According to the Kothari Commission of India as cited in Mukhopadhyay (2011), one of the key objectives of science education is to develop Scientific Creativity amongst learners. In Kenya, science education is also instrumental in the development of Scientific Creativity as students interact with the apparatus and develop various skills in the course of learning science (KIE, 2006).

Chemistry teaching in secondary schools form part of science education. The teaching of Chemistry constitutes Chemistry education (Bakshishi & Vimal, 2011). Chemistry education is a crucial instrument for national development, and relevant in maintaining the economic wealth of modern societies thereby justifying science skills among the young generations as essential for continued prosperity in the future (Bradley, 2005). Chemistry education plays an important role in enhancing quality of teaching and research as well as ensuring that the students are equipped with knowledge to produce goods and services to meet human needs for food, health, and industry (Emendu, 2014). Besides, the knowledge of chemistry plays a central role in linking Physics and Mathematics, Biology and medicine, and earth science and environmental science (Bakshishi & Vimal, 2012). This is possible because science

education offers an interdisciplinary approach to the science subjects taught in secondary schools.

Scientific Creativity is the ability to recognize the gaps in the problem, or the information, creating ideas or hypotheses, testing and developing these hypotheses and transmitting the data (Obote, 2016). According to Okere (1986) as cited in Ndeke (2003) Scientific Creativity is regarded as an individual's possession of the ability to be sensitive to scientific problems, to recognize relationships between patterns, general observations and scientific concepts and to have flexibility in reasoning. For the current study, Scientific Creativity refers to the level at which a student is sensitive to chemistry problems, recognizes relationships between patterns, general scientific observations and scientific concepts and is flexible in thinking when solving problems in Chemistry.

Scientific Creativity has several indicators. Yong, Sang, Jung and Ji (2009) identify Flexibility and Sensitivity as measurable indicators of Scientific Creativity. Yohan (2015) also identifies Recognition of relationships and patterns as another indicator of Scientific Creativity. Okere (1986) as cited in Obote (2016) and Njue (2016) gives the tenets or dimensions of Scientific Creativity as Sensitivity to scientific problems, Recognition of relationships, Flexibility in reasoning and planning for investigations. Sensitivity, recognition and flexibility are more universally accepted dimensions of scientific creativity. They are also more cognitive than planning for investigation (Chumo, 2014). Thus, the three dimensions are relevant and measurable in chemistry education. The study will therefore focus on Sensitivity, Recognition and Flexibility as the dimensions of Scientific Creativity.

Sensitivity is the ability to be aware of the scientific problems and to develop possible solutions to the identified problems in a scientific manner. It involves being aware of scientific problems or anomalies that others miss, and problem restructuring so that difficult problems become easier to solve (Jang, 2009). Recognition of relationships is the ability of the learner to identify relationships, patterns, similarities and connectivity among concepts and retrieving earlier experiences to solve a new problem or address a novel situation (Mukhopadhyay, 2011). Flexibility is the ability

to generate a variety of ideas when solving a scientific problem, even when it is not necessary to seek the many alternatives (Atkamis, Salin, Taskin & Ergin, 2008).

To increase Scientific Creativity among secondary school students, teachers should use appropriate teaching approaches that provide the opportunities that enhance acquisition of Scientific Creativity abilities (Okere & Ndeke, 2013). Such approaches are majorly constructivist based and include; Inquiry based learning, Problem based learning, Project based learning and Discovery teaching-learning approach (Prince and Felder, 2003). Gholamian, (2013) studied the effect of guided discovery learning approach on reinforcing the Scientific Creativity of sixth grade girl students in Tehran and reported that Discovery Teaching Approach increases Scientific Creativity among science students. Balim (2009) also investigated the effect of discovery teaching-learning approach on students' Scientific Creativity skills in Turkey and reported that Discovery Teaching Approach increases Scientific Creativity abilities amongst learners in biology. In a related study on effect of discovery method on secondary school students' achievement in physics in Kenya, Otiende, Abura and Barchok, (2013) partly reported that the method increased Scientific Creativity abilities among the learners. It stimulated Recognition of relationships that enabled the learners to form correct concepts, and enhanced Flexibility in reasoning that assisted learners to correct earlier formed misconceptions and solve problems in varied ways.

The secondary school Chemistry curriculum outlines various scientific creative abilities that students ought to attain. According to KIE (2006), should enable the learner to select and use appropriate apparatus for experimental work, make accurate measurements and observations, draw logical conclusions from experiments and identify patterns in the physical and chemical behavior of substances. These constitute some of the Scientific Creativity abilities that are implied in Sensitivity, Recognition and Flexibility. Chemistry instruction should prepare the learners for day to day problem solving by enhancing these abilities.

In the their study on determining the chemistry teacher's views of creativity in Turkey, Akkanat and Murat,2015 found that Scientific Creativity can be enhanced through instruction. This corroborates the findings by Mark and Keamy (2017). They investigated the relationship between pedagogy and Scientific Creativity and reported

that Scientific Creativity can be increased through the teaching approaches. However, students' level of scientific creativity has remained low in Kenya. This has been attributed to the teaching approaches used (Okere & Ndeke, 2013). Few studies have focused on teaching approaches and development of Scientific Creativity. The current study thus set to investigate the effect of discovery teaching approach on scientific creativity amongst students of chemistry in public secondary schools in Imenti North Sub-County.

Chemistry teaching involves use of different teaching approaches, methods and strategies. Teaching approaches can be learner-centred, teacher-centred or subject matter centred. Learner centred approaches are premised on the belief that the learner is an important participant in the process of learning. An example of the learner centred teaching approach in chemistry is the Discovery Teaching Approach (DTA).

Discovery Teaching Approach is an instructional approach through which students interact with their environment by exploring and manipulating objects, wrestling with questions and controversies and performing experiments (Brown & Ausburn, 2006). According to Levy, Thomas, Drago and Rex, (2013) Discovery Teaching Approach is an inquiry based instructional approach in which learners discover facts, relationships and new truths by themselves, with varying extents of guidance by the teacher who is the facilitator of learning. The greatest force behind Discovery Teaching Approach is learning by doing. This is because learners actively participate in the learning process and construct new knowledge based on their prerequisite knowledge.

Bruner (2009) proposes five main models by which Discovery Teaching Approach can be applied in the classroom situation. These models include guided discovery, open discovery, problem based learning, case based learning, incidental learning and simulation-based learning. This makes Discovery Teaching Approach a dynamic and versatile student centered approach that is appropriate in the teaching-learning of chemistry in high school. In the current study, the model adopted is mostly a hybrid of open discovery and guided discovery because it is broader and the extent of teacher guidance can be varied accordingly depending on the student needs in the course of

the lesson. However, use of Discovery Teaching Approach per se cannot be limited to just one model if all the students' needs in chemistry are to be addressed adequately.

Traditional Teaching Approaches are the common approaches used in a normal classroom instruction. They are teacher centred, where the teacher controls the learning environment, is the source of knowledge and causes learning to occur (Theroux, 2002). In Traditional Teaching Approaches, the teacher is the expert and the authority in presenting the information (Ahmad & Aziz, 2009). Traditional Teaching Approaches adopt expository methods of teaching such as lecture, memorization, demonstration, and discussion.

There are salient differences between Traditional Teaching Approaches and Discovery Teaching Approach, in terms of the inputs, procedures and out puts. According to Douglas and Chiu (2005), Discovery Teaching Approach is different from Traditional Teaching Approaches in that: learning is active rather than passive, learning is process-based rather than fact-based, failure is important, feedback is necessary and understanding is deeper. Discovery Teaching Approach recognizes the student as an active participant in the learning process, while in Traditional Teaching Approaches the student is a passive learner with the teacher as the expert (Adeyemi, 2008).

Discovery Teaching Approach provides the learner with first hand skills and knowledge in an interactive environment while in Traditional Teaching Approaches knowledge is transmitted from the teacher to the learners (Tanner, 2008). Besides, Discovery Teaching Approach is more effective in imparting Scientific Creativity abilities amongst learners than Traditional Teaching Approaches which encourage cramming of facts and high dependency among students (Tella, Indoshi & Othuon, 2010; Chika, 2012). Informed by the above assertions on the differences between the two approaches, Discovery Teaching Approach may be recommended in the instruction of science in order to inculcate Scientific Creativity (Longo, 2010).

Teaching approaches such as Discovery Teaching Approach has been associated with promotion of Scientific Creativity amongst secondary school students (Ali, 2013;

Akinbobola & Afolabi, 2010). In spite of this, the general level of Scientific Creativity amongst secondary school students in Kenya has been found to be low. In their study on relationship between secondary school students' chemistry self-concept and their Scientific Creativity in selected counties in Kenya, Wachanga, Kamonjo and Okere (2015) reported that the level of Scientific Creativity in secondary school students is low. This has been attributed to the use of inappropriate instructional approaches. Okere and Ndeke (2013) found out that secondary school students' levels of Scientific Creativity are low. This was attributed to the assertion that secondary school science teachers are not using the appropriate teaching approaches that would promote Scientific Creativity.

Teaching approaches have been associated with promotion of scientific creativity abilities among Chemistry students in secondary schools. Possession of Scientific Creativity is related to the achievement in Chemistry (Kamonjo, Okere & Wachanga, 2015). However, performance in Chemistry in Imenti North Sub-County has been unsatisfactory (KNEC, 2016). According to the Imenti North Sub-County Director of Education's KCSE Chemistry report for 2016, performance in Chemistry in the Sub-County was not satisfactory. This could be attributed to low Scientific Creativity and teaching approaches. Though teaching approaches are expected to enhance Scientific Creativity which in turn influences achievement, performance in Chemistry in Imenti North has remained relatively low. This is possibly due to the teaching approaches applied in Chemistry instruction in secondary schools. However, this relationship is not strongly established. Therefore the current study sought to find out the effect of Discovery Teaching Approach on Scientific Creativity amongst students of Chemistry in Public Secondary Schools in Imenti North Sub-County.

1.2 Statement of the Problem

Scientific Creativity is important for the socio-economic development of the society. To this end, the secondary school Chemistry curriculum is meant to prepare students who possess Scientific Creativity abilities, who are capable of solving day to day problems. The students should also be able to achieve personal and societal development. One of the general objectives of secondary school Chemistry learning in Kenya is to develop Scientific Creativity to solve problems in any situation. The

students should be able to select and use appropriate apparatus for experimental work, make accurate measurements and observations, draw logical conclusions and identify patterns in physical and chemical behavior of substances. These abilities are expected to be developed during Chemistry instruction. Chemistry teaching approaches are therefore expected to enhance learners' Scientific Creativity. However, Scientific Creativity levels amongst Chemistry students have remained low leading to unsatisfactory achievement in Chemistry. This could be attributed to the teaching approaches in use. But this relationship is not clearly established. Therefore, the present study sought to determine the Effect Discovery Teaching Approach on Scientific Creativity amongst students of Chemistry in Public Secondary Schools in Imenti North Sub-County.

1.3 Purpose of the Study

The purpose of the study was to investigate the effect of Discovery Teaching Approach on Scientific Creativity amongst form three students of chemistry in Public Secondary Schools in Imenti North Sub-County, Kenya.

1.4 Research Objectives

The following were the objectives of the study.

i. To investigate the effect of Discovery Teaching Approach on students' Sensitivity to chemistry problems.
ii. To determine the effect of Discovery Teaching Approach on students' Recognition of relationships in chemistry.
iii. To find out the effect of Discovery Teaching Approach on students' Flexibility in reasoning in solving chemistry problems.

1.5 Research Hypotheses

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

H_{01}: There is no statistical significant difference in Sensitivity to chemistry problems between students subjected to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches.

H_{02}: There is no statistical significant difference in Recognition of relationships in chemistry between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches.

H_{03}: There is no statistical significant difference in Flexibility in reasoning in solving chemistry problems between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches.

1.6 Significance of the Study

The findings of this study will be useful to curriculum developers at the Kenya Institute of Curriculum development (KICD) to advise chemistry teachers on the approaches to use when implementing the chemistry curriculum so as to enhance scientific creativity. The results will be used by the universities and diploma secondary school teacher training colleges to adequately prepare science teachers on the use of Discovery Teaching Approach in relation to scientific creativity. The results of the study may also be useful to Center for Mathematics, Science and Technology Education in Africa (CEMASTEA) trainers in planning the in-service trainings for science teachers aimed at promoting scientific creativity in secondary schools. The results of the study will also form the basis for further research in the use of Discovery Teaching Approach in enhancing Scientific Creativity in other subjects.

1.7 Scope of the Study

The present study was conducted in County Public Secondary in Imenti North Sub-County, Kenya. The target population was all the students in Public secondary schools and involved a sample of 186 Form Three students. Form Three syllabus was used because the topic of the 'Mole' is taught at this level according to the syllabus. The study period was five weeks and CCT and CCCOS were used for data collection. Solomon-Four Group Non-Equivalent Control Group design was used. The study focused on the effect of Discovery Teaching Approach on Scientific Creativity abilities of Sensitivity, Recognition and Flexibility in chemistry among Students in Public Secondary Schools in Imenti North Sub-County.

1.8 Limitations of the Study

The use Chemistry Creativity Test (CCT) to measure scientific creativity would have been limiting because it collected quantitative cognitive capability data only. To overcome the challenge, the researcher incorporated Chemistry Classroom Creativity Observation Schedule (CCCOS) which collected quantitative data to supplement the quantitative data collected by CCT. The study was conducted earlier than the time stipulated in the chemistry schemes of work to teach the Mole. This was addressed by the teachers involved restructuring the schemes so as to teach Mole earlier and Gas Laws at later date.

1.9 Assumptions of the Study

The responses provided by the respondents were honest and accurate. It was also assumed that the teachers taught as per the teaching manual and followed the implementation schedule throughout the intervention period.

1.10 Definition of Operational Terms

The following are the definitions of the terms used in the study.

Constructivism refers to the psychological epistemology that argues that knowledge and meaning is derived from experiences. In the present study, it implies generation and acquisition of knowledge and skills through explorative activities provided in Discovery Teaching Approach.

Creative abilities- These refer to sensitivity to scientific problems, recognition of relationships and flexibility in reasoning as tenets of creativity. In the present study, it referred to the manifestations of scientific creativity abilities in learners.

Discovery Teaching Approach-is a model of instruction that takes into account all strategies and techniques that are aimed at allowing the learners to interact with their environment, explore and discover knowledge and ideas. In the present study, the approach involved various strategies, methods or techniques through which the learner will learn by discovery and develop scientific creativity.

Effect – The behavioral or mental change that the subjects undergo or exhibit after being exposed to an intervention. In this study, effect referred to a change in scientific creativity level resulting from the discovery teaching approach employed by the teacher.

Flexibility – Flexibility is the ability to generate a variety of ideas when solving a scientific problem, even when it is not necessary to seek the many alternatives. In the current study, it referred to number of different solutions, and/or different methods of coming to the solution in a given problem in chemistry. It was deduced through students' score in CCT and frequency data in CCCOS.

Instruction – Process or act of imparting knowledge. In this study it meant application of Discovery Teaching Approach in development of creativity abilities amongst the learners.

Recognition- refers to the ability of noting, sensing, or seeing and applying of relationships, patterns, similarities and earlier experiences

in solving given problems in science. In the present study, recognition refers to the ability to relate formulae, identify relationships between patterns, general observations and scientific concepts when solving problems in chemistry.

Scientific Creativity –Refers to the ability to be aware of scientific problems, think of possible solutions to the problems and test practicability of the solutions. In the present study, it implied possession of skills of sensitivity to problems, recognition of relationships between patterns, general observations and concepts and flexibility in reasoning when solving problems in chemistry

Sensitivity- is the ability to identify incorrect solutions, formula, fallacious arguments and statements in chemistry. In this study, it was revealed through students' scores in CCT and frequency data on CCCOS

Teaching – is an interactive process through which knowledge and skills are shared with students, with a view to improving students' ability to manipulate the social, economic, political and physical environment to enhance their survival. In the present study, teaching meant all the activities carried out by the teacher in endeavor to ensure that learners gain or explore knowledge by use of discovery in instruction.

Teaching approach- This is an instructional design which is explicit at the level of theory of learning, but can be applied in many different ways at the level of objectives, teacher and learner roles, and activities. In this study, the approach meant application of the various methods, strategies and techniques that will promote teaching-learning through discovery.

Traditional Teaching Approaches –refers to the commonly used teaching approaches in daily classroom instruction. In the study, traditional teaching approaches meant all teaching approaches that are not discovery teaching approach.

CHAPTER TWO
LITERATURE REVIEW

2.1 Science Education

Science education refers to the study of inter-relationships between science as a discipline and the application of educational principles to its understanding, teaching and learning (Chioma, 2015). According to Hudson (2005), science education consists of three areas namely, learning science, learning about science and doing science. Hudson further asserts that doing science involves engaging in the developing expertise in scientific inquiry and problem solving which promotes development of mental skills and abilities. Science education is the field of science that is concerned with sharing of science content and the process of teaching science pedagogy in order to provide expectations for the development of understanding part of the scientific community. Besides, Kola (2013) defines science education as the field concerned with sharing science content and process with individuals not traditionally considered part of scientific community. The learners may be children, college students or adults within the general public. Science education can be taught at different schooling levels; primary, secondary, post-secondary and adult levels (Kola, 2013).

The field of science education includes work in science content, science process, and teaching pedagogy. Science education is intended to be an essential vehicle to provide human resource development, modernization and overall development of countries. It is also intended to encourage people to question and search for data (Yasemin, 2004; Black & Harrison, 2004). Secondary school science education involves physics, biology and chemistry. Chemistry is an enabling discipline that underpins the sciences, environment, medicine, forensics, space sciences and industry (Royal Society of Chemistry, 2015). Yavon, Evans & Karabinos as cited in Njagi and Njagi (2015) posits that chemistry plays an important role in most aspects of modern science and technology, from biotechnology to the creation of new materials and medicines.

The study of teaching and learning Chemistry in all schools, colleges and universities constitutes chemistry education. Secondary school Chemistry syllabus emphasizes on development of creative abilities in students by stating that learners should; select and handle appropriate apparatus for use in experimental work, make accurate

measurements, observations and draw logical conclusions from experiments, use knowledge and skills acquired to solve problems in everyday life, identify patterns in the physical and chemical behavior of substances; apply the knowledge acquired to promote positive environmental and health practices, apply the principles and skills acquired for technological and industrial development, acquire adequate knowledge in chemistry for further education and for training (KIE,2006; KNEC, 2007; Wachanga, Kamonjo & Okere, 2015). This is the basis of Scientific Creativity in chemistry. Thus, the role of chemistry in the development of the Scientific Creativity base of a country cannot be underestimated.

2.2 Scientific Creativity

Scientific Creativity refers to the ability to be aware of scientific problems, think of possible solutions to the problems and test practicability of the solutions. According to Obote (2016), Scientific Creativity is the ability to recognize the gaps in the problem or the information, creating ideas or hypotheses, testing and developing these hypotheses and transmitting the data. It is the ability to find new problems and the ability to formulate hypotheses involving some addition to prior knowledge. Scientific Creativity is different from other creativity since it is concerned with creative experiments, creative scientific problem finding and solving, and creative science activity. Yong, Sang, Jung and Ji (2009) identify Flexibility and Sensitivity as some of the Scientific Creativity abilities or aspects that can be enhanced in a classroom situation. Okere, (1986) as cited in Wachanga, Okere and Kamonjo (2015), gives the psychological definition of Scientific Creativity that focuses on four abilities of fluency, Sensitivity, Flexibility and planning. These abilities are seen as the measures for Scientific Creativity which have relevance in science education.

Use of appropriate teaching approaches such as Discovery Teaching Approach can be effective in propagating Scientific Creativity in chemistry. The most convenient consideration of Scientific Creativity in chemistry teaching connects it with the experimental nature of chemistry (Taylor, 2017). Experimental and theoretical work will be more successful if students are placed in a position where they can discover facts, define problems, present ideas, propose solutions and decide on the most

acceptable ones, as possible. This is possible through use of Discovery Teaching Approach.

According to Okere (1996) as cited in Obote (2011), and Runco and Garret (2012), there are four tenets of creativity which form the dimensions of Scientific Creativity. These are: Sensitivity to scientific problems, Recognition of relationships, Flexibility in reasoning and planning for an investigation. These dimensions of Scientific Creativity are the creative abilities that learners can acquire and make use of in their lives. These creativity abilities make the learners to be sensitive to problems, empowers them to recognize patterns, similarities and relationships and have flexibility in generation of ideas as well as be able to generate associated ideas along the same line of thought. These abilities constitute the measures of creativity that are relevant in science education and more so to chemistry owing to its importance in the society. These dimensions constitute what Okere (1996) as cited in Obote (2011) presents as the psychological definitions of creativity and these have direct relation to science education as each psychological definition has a concomitant scientific definition. The present study focuses on Sensitivity to scientific problems, Recognition of relationships and Flexibility in reasoning.

Abdullah, (2015) investigated the effect of guided discovery approach in teaching creativity in Japan and found out that guided discovery approach enhances creativity in science. Otiende, Barchok, and Abura (2013) investigated the effect of discovery method on students' achievement in physics and partly found that the method increases Scientific Creativity abilities of Sensitivity, Recognition and Flexibility. The current study investigated the effect of Discovery Teaching Approach on students' Scientific Creativity abilities of Sensitivity, Recognition and Flexibility in relation to chemistry education.

2.2.1 Sensitivity to Chemistry Problems

This is the ability to be aware of the problem and thinking of possible solutions to the identified problem. The ability makes the student to note and criticize the errors on given problems when wrong calculations, formulae and solutions are given. Sensitivity is an important aspect of Scientific Creativity because finding creative

problems to solve is an important trait of a good scientist. Creative persons have the ability to sense scientific problems, formulate hypotheses, analyze the problem and generate hypothesis to solving the problem (Kumar & Mukhopadhyay, 2013). Sensitivity is a prerequisite to scientific Creativity; it also feeds creativity (Buck, 2016). Without Sensitivity there cannot be Scientific Creativity because Sensitivity is the precursor to Scientific Creativity (Deborah, 2011). Sensitivity involves the ability to ask different questions and approaching solutions to problems in different ways, and not necessarily the instant solution to the problem.

Persons with Sensitivity ability are more aware of their environment than others. They are highly creative and intuitive (Elaine, 2011). According to Chumo (2014), Sensitivity to scientific problems involves a student reformulating a general statement so as to make it scientifically testable, citing sources of errors and suggesting the control variables in an experiment. James and Bruce, (2001) notes that a creative learner should be able to identify the problem cite and concentrate on defining the problem appropriately. When wrong or fallacious calculations are given, the student should be able to rectify and do the right calculations. The ability can be assessed by setting problems that require students to identify possible sources of experimental errors or criticize experimental procedures (Erdogan & Akkanat, 2014).

In chemistry, wrong formulae, calculations and procedures are given to students to clarify and do correct calculations from wrong solutions. In a study, by Okere (1996) as cited in Chumo, (2014) required students to suggest reasons why the given experimental procedure was not fair. It was found out that learners who were able to make correct criticisms on the procedure and identify dependent and independent variables were creative. Sensitivity to problems enables the learner to note and criticize the errors on given problems based on wrong calculations, formulae and erroneous solutions (Chumo, 2014). In this study, Sensitivity was determined from the scores obtained by the students in the Chemistry Creativity Test (CCT) and frequency data from Sensitivity arrays in Chemistry Class Creativity Observation Schedule (CCCOS). Safavi (2007) studied methods and techniques of teaching science in Iran and reported that Discovery Teaching Approach enhances Sensitivity among secondary school students.

2.2.2 Recognition of Relationships

This is the ability to recognize relationships, patterns, similarities and connectivity among concepts and retrieving of the earlier experiences whenever one encounters a new situation or problem (Bruner, 2009). Recognition of relationships between patterns, general scientific observations and scientific concepts is an important skill in chemistry learning. Yohan (2015) asserts that creativity has a connection with pattern recognition which enables one to draw analogies between seemingly very different topics. Students are able to generate hypothesis once they recognize relationship of facts, patterns and ideas in a particular observation or phenomena. The ability to recognize patterns is based not only on the capacity to make connections between ideas and concepts but also intuition and experience. Intuition promotes imagination, which must be evaluated through reasoning (Hodgkinson, Langan & saddler, 2008). Capability to recognize existing patterns is essential for creative decision making and planning. Pattern recognition serves processing, classification, exploration, discovery and creative implementation and it helps to raise consciousness and build comprehensiveness (Darlington, 2015).

The ability to recognize patterns and relationships enables one to consolidate predictions into a system. For instance, Mendeleev predicted existence of elements and their characteristics by recognizing patterns and gaps between the elements in the periodic table he had earlier developed (Olga, 2017). Finding new patterns means paying attention to new details and approaching a problem from a new perspective. This makes pattern Recognition an aspect of Scientific Creativity that is important for innovations to occur. Thinking outside the patterns and growing parallel processes expands the learners' mind promoting Scientific Creativity and enhancing innovative thinking (Hodgkinson et al, 2008).

Recognition of relationships and patterns is one common ground between the existing knowledge and the new scientific concepts. In learning through patterns, meaning is derived from relationships, not disconnected facts (Kavanagh, 2006). This ability to recognize relationships and connect new knowledge with previous understandings, patterns and experiences is called Recognition of relationships. Learners who are able to make connections and "chunk" related information into categories and relationships

can retain more knowledge and develop more creative abilities than those who learn by rote (Gobet, 2005)

Learners with the Recognition ability are able to use earlier experiences to solve new problems based on the already established trends, patterns and connectivity between existing knowledge and newly encountered information (Erdogan & Akkanat, 2014. Recognition of relationships is expressed in a science classroom when a learner is able to recognize relationships between everyday scientific observations and the concepts acquired from science lessons (Okere & Ndeke, 2013). In this study, students' responses on Recognition items in the Chemistry Creativity Test (CCT) and frequency data in Chemistry Classroom Creativity Observation Schedule (CCCOS) was used to determine their level of Recognition of relationships between patterns, general observations and chemistry concepts.

Recognition of relationships can be applied in chemistry when, for instance, a student is required to determine the relative atomic mass of an element present in the formula of a compound taking part in a chemical reaction during a titration experiment provided the reacting moles or mole ratios are given. Such application is possible when using Discovery Teaching Approach because students are able to interact with their learning environment and explore various formulae and apply them in different calculations. In the present study, students' Recognition of relationships between patterns, general scientific observations and scientific concepts in chemistry were determined from their scores in test items on Recognition in CCT and Frequencies of Recognition arrays obtained in CCCOS.

2.2.3 Flexibility in Reasoning

Flexibility is the ability to "change tact", not to be bound by an established approach after that approach is found to no longer work efficiently (Atkamis, 2008). It means generation of a large number of responses and ideas across different categories, which in turn simplifies problem solving (Darlington, 2015). Besides, Flexibility is the ability to look at something from a different angle or point of view, shifting to an opposing viewpoint, angle, direction or modality. It is when a learner is able to generate a variety of ideas when solving a problem even when it is not necessary to do

so. Flexibility plays a critical role in the ability of high creative individuals to generate novel and innovative ideas (Kenett, Levy, Stanley, Faust, and Havlin, 2018).

According to Smith and Ward, (2012), Flexibility is the ability to break apart from the mental fixations when solving a problem. Higher levels of cognitive Flexibility facilitate higher levels of Scientific Creativity and are indicative of higher Scientific Creativity (Vartanian, 2009). Flexible learners provide more than one solution to a given problem. Jeffrey, (2005) points out that creative ideas are generated when one discards preconceived assumptions and attempts new methods that may seem otherwise unthinkable to others. It often leads to original ideas and solutions (Ibrahim, 2012). Flexible thinkers may flip through alternatives and alternate approaches and ultimately build better reasoning with different viewpoints of the solutions

According to Okere and Ndeke, (2013) creative thinkers are flexible thinkers. They abandon old thinking ways and strike out solutions in new directions. Hudson (2005) asserts that flexible learners are not fixed to one dimension of reasoning but have open approaches to problems. They speculate possibilities and ask the questions as well as visualize the alternatives to the solutions leading to diverse viewpoints. Flexibility in reasoning can be enhanced in the classroom by asking questions and designing projects where students must shift perspective or by considering different possible causes for the same phenomenon, and making alternative hypotheses in designing an experiment.

Flexibility involves examination of a problem from several points of view so as to develop a multifaceted approach to solving it. Flexibility in Scientific Creativity has been related to originality of ideas and the ability to break apart from mental fixations (Smith & Ward, 2012). In the current study, students' Flexibility levels were determined from their scores in Chemistry Creativity Test and frequency data in Chemistry Classroom Creativity Observation Schedule. Ali (2013) studied the effect of guided discovery learning on reinforcing the creative thinking of sixth grade girl students in Tehran and reported that Discovery Teaching Approach enhances Flexibility in reasoning amongst the students. In the present study, students were taught using Discovery Teaching Approach and their level of Flexibility in reasoning

determined after the teaching period. Flexibility in reasoning was assessed from the students' scores in test items on Flexibility in CCT and Flexibility observation frequencies recorded in CCCOS after they were taught using Discovery Teaching Approach.

2.3 Discovery Teaching Approach

Discovery Teaching Approach is an inquiry-based approach anchored in constructivist learning theory that takes in problem solving situations where the learner draws from own past experiences and existing knowledge to discover facts and relationships and new truths to be learnt in an explorative learning environment (Bruner, 2009). According to Prince and Felder (2006), Discovery Teaching Approach is an inquiry-based approach in which students are given a question to answer, a problem to solve, or a set of observations to explain, and then work in a largely self-directed manner to complete their assigned tasks and draw appropriate inferences and outcomes, discovering the desired factual and conceptual knowledge in the process. In the present study, the model of Discovery Teaching Approach adopted is both open and guided discovery. This provides a more versatile approach to chemistry instruction without limiting the learner or the teacher. This broader approach also helps in reducing the disadvantages that have been associated with either open or guided discovery.

A teaching approach is an enlightened viewpoint toward teaching. It provides philosophy to the whole process of instruction and guides the teaching methods and techniques. Approach gives the overall wisdom; it provides direction, and sets expectations to the entire spectrum of the teaching process. Furthermore, approach sets the general rule or general principle to make learning possible (Jack & Miia, 2007). A teaching approach is also described as a set of principles, beliefs and ideas about the nature of learning which is translated into the classroom (Landaverde, 2013). According to Felder and Brent (2003), a teaching approach is a description of how we go about teaching our students in terms of what we do when we teach, the planned teaching and learning activities and the way in which we engage the students. The Principles of an approach can be applied in many different ways and therefore, teachers adopting an approach have a considerable level of flexibility in how they

apply the principles in their contexts. Teaching approaches are either teacher-centred or learner-centred. Most of the learner-centered approaches are constructivist based and encourage active participation of the learner in construction of knowledge in the process of learning. They are mostly the inductive teaching-learning approaches. Discovery Teaching Approach is an example of learner centered approach that can be applied in the teaching of Chemistry.

Discovery Teaching Approach is based on the student finding things out for themselves, looking into problems and asking questions. It is an inquiry-based approach, which enables learners to discover facts and relationships, new truths to be learned by themselves, with varying extents of guidance by the teacher who in this case acts as the facilitator of learning (Best & Thomas, 2007). According to Ormrod, 1995 as cited in Ali (2013), Discovery Teaching Approach is an approach by which learners are encouraged to interact with their environment, explore, manipulate objects and questions and experiments to understand the subject matter. Discovery Teaching Approach is broadly based on constructivism as postulated by Vygotsky, who is considered the father of constructivism. Vygotsky's view of constructivism focused on understanding social and cultural conditions for human learning. These ideas on constructivism are the most relevant for teaching and learning science (Taber, 2006). Vygotsky's Theory of Constructivism was adopted by Piaget and Bruner who viewed constructivism in slightly different approaches. Piaget based his examples on philosophy and epistemology while Bruner focused on cognitive structure which he called mental schema (Culata, 2019).

Discovery Teaching Approach is broadly based on Bruner's view of Constructivism that learning is an active process in which learners construct new ideas based upon their past and current knowledge. This is what he terms mental schemata. Bruner is considered the father of Discovery Teaching Approach. One assertion by Bruner that highlights this viewpoint is as cited in Sj□ berg (2007), that "Emphasis on Discovery Teaching Approach has precisely the effect on the learner of leading him to be a constructionist, to organize what he is encountering in a manner not only designed to discover regularity and relatedness, but also to avoid the kind of information drift that fails to keep account of the uses to which information might have to be put". The

greatest force behind discovery is 'learning by doing'. This implies that through Discovery Teaching Approach, learners create, integrate and generalize knowledge (Gengle, Abel & Mohammed, 2017). This is in line with assertions by Saab, Van Joolingen and Van Hout-Wolters (2005) that in discovery learning, students construct knowledge based on new information and data collected by them in an explorative learning environment.

Discovery Teaching Approach involves learning through inquiry and exploration (Bybee, Powell & Trowbridge, 2008). It includes various instructional designs and models that engage students in learning through discovery. Discovery Teaching Approach provides for deeper and more practical learning opportunities. Learners internalize concepts when they go through a natural progression to understand them (Riandari, Susanti & Suratmi, 2018). According to Kibirige, Osodo and Mirasi (2013), Discovery Teaching Approach is different from Traditional Teaching Approaches in that: learning is active rather than passive, learning is process-based rather than fact-based, failure is important, feedback is necessary and understanding is deeper.

One of the pedagogical aims of Discovery Teaching Approach is the promotion of Scientific Creativity. Discovery Teaching Approach is recommended in the instruction of science in order to inculcate Scientific Creativity (Longo, 2010). Besides, in Discovery Teaching Approach, the teacher is the facilitator rather than the primary source of information or dispenser of knowledge (Roh, 2003). Discovery Teaching Approach has several models of execution namely; collaborative discovery learning, experimental learning, guided discovery, learning by exploring, simulation based learning, and inquiry based learning.

However, since learners are left to self-discovery of concepts and facts, researchers worry that learning that take place may have errors, misconceptions or be confusing or frustrating to the learner (Alfieri, Brooks, Aldrich & Tenenbaum, 2011). These fears can be allayed by the teacher taking the role of the guiding expert and a motivator throughout the chemistry instruction by discovery approach. Bruner (2009) proposes five main models of discovery learning as: open discovery, guided discovery, Problem based learning, case based learning, incidental learning and

simulation-based learning. This makes Discovery Teaching Approach a dynamic and versatile student centered approach that is appropriate in the teaching-learning of chemistry in high school.

Discovery Teaching Approach has a number of advantages as cited by various scholars. Bruner, (2009) identifies advantages of Discovery Teaching Approach as encouraging active engagement of learners, promoting motivation as it allows individuals to experiment and discover for themselves, promotion of Scientific Creativity, critical thinking and problem solving skills, fostering curiosity and interest, and enabling the development of lifelong learning skills. According to Christopher (2014), Discovery Teaching Approach encourages Scientific Creativity and discourages plain retention of facts. It also allows learners to seek information that satisfies their curiosity (Chin, 2004). A number of disadvantages have been associated with this approach. It is however agreed mostly that mature science students can effectively be taught through Discovery Teaching Approach and end up with great mastery of concepts and skills (Mayer, 2004; Kirschner, Sweller and Clark, (2006).

Several studies have been carried out in different parts of the world with regard to Discovery Teaching Approach. Rinita, Prasojo, and Arifai (2018) investigated on improving Senior High School students' creativity using discovery learning model in Sumatra and reported that Discovery Teaching Approach increases students' Scientific Creativity abilities. Balim, (2009) also found out that Discovery Teaching Approach improves students' academic success and inquiry skills in Malaysia. Abdullah, (2015) investigated the effect of guided discovery approach in teaching Creativity in Japan and found out that guided discovery enhances creativity in science.

In Nigeria, it was found that guided discovery approach improved students' academic performance in chemistry as compared to expository teaching approaches (Udo, 2011). Otobo (2012) also studied effect of discovery method of instruction on the achievement of junior secondary school students in Nigeria and found out that Discovery Teaching Approach enhances students' Scientific Creativity to solve day to

day problems. Akinyemi and Afolabi (2010) also investigated the Effect of Constructivist Practices through Guided Discovery Approach on Students' Cognitive Achievement in Nigerian Senior Secondary School Physics Students. Their findings were that guided discovery approach enhanced students' ability to recognize relationships between methods and solutions and use them to make generalizations and conclusions.

In their study in Kenya, Otiende, Abura and Barchok, (2013) found that teaching by discovery increases students' Scientific Creativity in physics, enabling them to be able to respond to unique problems and situations. They also found out that teaching by discovery stimulated students' Recognition of relationships between concepts and also allowed for Flexibility in reasoning which helps the learners to do away with previous misconceptions. To establish the relationship between Discovery Teaching Approach and Scientific Creativity in chemistry, the present study investigated the Effect of Discovery Teaching Approach on Scientific Creativity amongst Secondary School Chemistry Students in Imenti North Sub-County, Kenya.

2.4 Teaching Approaches in Chemistry

There are other common teaching approaches that are applied in the chemistry classroom. These approaches are either Constructivist based learner-centred teaching approaches or Traditional Teaching Approaches used in chemistry teaching. Some of the Constructivist based teaching approaches include: Inquiry Based Approach, Problem Based Approach, and Project Based Approach.

Constructivist based teaching approaches are the inductive teaching and learning approaches adopted by teachers in the course of instruction. Inductive approaches start with a set of observations or data to interpret, or a complex real world problem, and as the learners study the data or problem, they generate a need for facts, procedures and guiding principles. The constructivist based inductive teaching/learning approaches have several subsystems which includes; Problem based learning, Inquiry based learning, Project based learning, Case based learning and discovery learning (Prince & Felder, 2003). All these approaches have common characteristics which include: they are learner-centered, active learning is about

doing, development of self-directed learning skills, promotion of scientific creativity, and creation of knowledge by learners rather than being passive learners (Healey, 2005).

2.4.1 Inquiry Based Approach

Inquiry based approach involves learning by doing and very closely related to the development and practice of thinking skills (Dorstal, 2015). It is also called Inquiry Based Learning (IBL). The major goal of inquiry based approach is for students to develop valuable research skills and be prepared for long-life learning. The salient features of Inquiry Based Learning Approaches are that the learning is stimulated by inquiry. Learning is based on process of seeking knowledge, learning is learner-centered, enhances development of mental skills and the teacher is a facilitator of learning (Lee, 2004). However, some negative aspects of Inquiry Based Learning include: a perceived higher workload and student anxiety over the need to become self-directed learners (Plowright & Watkins, 2004). This approach places greater emphasis on students' self-directed learning and training, enhances students' research ability while learning.

2.4.2 Problem Based Learning Approach

In Problem Based Learning (PBL), the learners learn according to their own needs and pace (Orhan & Ruhan, 2006). According to Kozbelt, Beghetto and Runco, (2010), with the increasing quest for the development of skills pertaining to creativity, there is a call for paradigm shift in education so as to embrace more learner centered instructional approaches. Students who learn by PBL become independent and long life learners and can continue to learn in their whole life (Riasat, 2010). In a PBL environment, students act as professionals and are confronted with problems that require clearly defining, and well-structured problems, developing hypotheses, assessing, analyzing, utilizing data from different sources, revising initial hypotheses as data is collected and justifying solutions based on evidence and reasoning (Gallagher, & Gallagher,2013).

2.4.3 Project Based Learning Approach

Project Based Learning is an instructional approach in which students learn important skills by doing actual projects. Students apply core academic skills and creativity to solve authentic problems in real world solutions (Renata, 2008). The approach is built on learning activities that have brought challenges for students to solve. Learners work in groups to achieve a common goal. As students interact with each other and with materials, they not only gain the content but also the important skills such as research and inquiry skills, creativity and critical thinking (Goodman & Stivers, 2010).

2.5 Traditional Teaching Approaches in Chemistry

Teaching approaches in chemistry are either teacher-centred or learner-centred. However, learner-centred teaching approaches are more superior to teacher-centred teaching approaches (Barrow, 2010). Teacher-centered approaches are also known as Traditional Teaching Approaches. Traditional Teaching Approaches are associated with conventional methods where teachers are at the center of classroom activities. Such methods include Lecture, Explanations and Discussions and Demonstrations (Ahmad & Aziz, 2009).

Traditional Teaching Approaches are the common approaches used in the normal classroom teaching. They are teacher centred, where the teacher controls the learning environment, is the source of knowledge and causes learning to occur (Theroux, 2004). In Traditional Teaching Approaches, some teachers believe that lessons should be teacher-centered, where the teacher is the expert and the authority in presenting information (Ahmad & Aziz, 2009). Nevertheless, teacher-centered methods are associated with inadequate stimulation of students' innovative capacities, intellectual thinking, and memorization, cramming of facts, poor knowledge retention and high dependency among students (Adeyemi, 2008; Tanner, 2009; Tella, Indoshi and Othuon, 2010). Traditional Teaching Approaches are mostly expository and depict the teacher as the expert and centre of knowledge. Traditional Teaching Approaches adopt expository methods such as lecture, drilling, memorization, demonstration and discussion. These are the common day to day methods of teaching.

A teaching method refers to the general principles, pedagogy and management strategies used for classroom instruction. According to Chelule, (2009) a suitable teaching method should be determined by the nature of the subject matter and the objectives to be attained, number of students involved, time available, interest and abilities of the teacher, facilities and materials available.

A chemistry teacher has the opportunity to use various teaching methods in endeavor to implement the objectives of chemistry teaching as outlined in the secondary school chemistry syllabus. Through chemistry instruction, various mental and psychomotor skills can be developed such as observation, manipulation, calculation, analysis, investigation and application (KIE, 2006). Although teachers have the discretion to choose methods for delivering lessons to their students, Chika (2012) observes that learner-centered pedagogy is powerful for improving application of knowledge and skills acquired. The conventional methods of teaching chemistry have commonly been used for many years. They are closely associated with Traditional Teaching Approaches. Some of these methods include Lecture, Discussion and Demonstration.

2.5.1 Lecture Method

Lecture is the most commonly used method of teaching chemistry (Kumar, 2002). The method is commonly used in colleges and secondary schools to handle large classes. In lecture method, only the teacher talks and students are passive listeners. The method entails transmission of factual knowledge from the teacher to the learner. Due to lack of participation, students get bored and may end up losing interest and power to reason. Lecture is advantageous in that it is simple, fast and cheap method to present the vast issues to a lot of groups of learners in a short time (Ameh and Dantani, 2012).

Lecture method is disadvantageous due the inactiveness of the learners, tiring long lectures, one-way communication and fast forgetting of issues. This is because during a lecture, there is more emphasis given to theory without any practical and real life situations (Damodharan and Rengarajan, 2007). Also, Adeyemi (2008) notes that lecture, which is the most common traditional method, does not stimulate students' innovation, inquiry and scientific thinking but rather encourages students to cram

facts, which are easily forgotten. McDowell (2001) further notes that instructional methods that encourage memorization and reproduction are short of knowledge that can be used to solve problems in new situations. Tella, Indoshi and Othuon (2010) noted that teacher-centered methods like lecture often result to students not enjoying lessons and missing the benefits of intellectual discovery.

2.5.2 Demonstration Method

Demonstration is a teaching method that links explanation with practice (Afolabi and Akinbobola, 2010). The teacher shows and explains to the learners how to carry out a certain procedure. A good demonstration exercise helps students to understand the lesson clearly as it teaches concepts and principles by combining oral explanation with the handling or manipulation of real things (Motshoane, 2006). According to Akinbobola and Afolabi, 2010), demonstration method involves introduction of apparatus to learners for proper use, encourages learners' use of apparatus by initiating the correct methods of apparatus use, and the learner shown those experiments that cannot be carried out by each learner due to the danger levels, cost or complexity involved. But due to lack of direct practical involvement of the learners, the learners may end up being passive and fail to get the intended skills.

2.5.3 Discussion Method

Discussion method is one in which a teacher and the learner talk together in order to share opinions, views or information about a topic. Learning is by verbal interaction with others and the method enhances learners' participation through talking. When students participate in a discussion, they can challenge each other's ideas hence lead to more permanent learning (Holger and Schmidt, 2004). Discussion Method encourages cooperative teamwork between teacher and students and amongst students themselves. It emphasizes the need for all to work cooperatively while developing societal relationships (Omatseye, 2007). Such cooperative learning improves both academic achievement and students' interpersonal relationships. Out of the discussions, the teacher is also able to identify the students' misconceptions and be able to address them through clarifying concepts. But in some cases, the low achievers may shy away from sharing their ideas or points of understanding for fear of

being laughed off, mocked or criticized. Discussion method is therefore a plausible way of teaching chemistry but by itself, it is not sufficient in chemistry instruction.

2.6 Theoretical Framework

The study was guided by two Theories: Gardner's Theory of Multiple Intelligence and Okere's Model of Scientific Creativity.

2.6.1 Theory of Multiple Intelligences

Howard Gardner's Theory of Multiple Intelligence (1983) is also referred to as Gardner's Theory of Creativity. The theory postulates that individuals have creative abilities/ strengths that are domain-specific. Gardner proposes nine intelligences namely: linguistic, logical-mathematical, musical, spatial, bodily, interpersonal, intrapersonal, naturalistic and existential. According to the theory, logical-mathematical intelligence comprises of the capacity to analyze problems logically, carry out mathematical operations, deduct patterns deductively, think logically and investigate issues scientifically.

The above aspects of the logical-mathematical intelligences form the basis for the Scientific Creativity abilities of Sensitivity to scientific problems, Recognition of relationships between patterns, general scientific observations and scientific concepts, and flexibility in scientific reasoning. Individuals possessing these abilities fit to be engineers, scientists, analysts, and statisticians who are important to the socio-economic development of any society. A learner who has ability to detect patterns for example, will be able to establish the relationship between the patterns and be able to come up with a new understanding of the concept (Anastacia, Maura & Tyler, 2014). This is the basis for the Recognition of relationships in the course of learning sciences like biology, chemistry and physics.

In the present study, students were expected to develop Scientific Creativity abilities of Sensitivity, Recognition and Flexibility as implied in Gardner's theory of Multiple Intelligence through chemistry instruction by Discovery Teaching Approach. They were to think of the chemistry problems, find possible solutions, critique existing solutions and correct errors and mistakes in various statements. This was possible through critical analysis of problems and exploration. Using Discovery Teaching

Approach in teaching chemistry provided opportunity for such explorative learning experiences. The learners were expected to identify errors in fallacious calculations, formulae and procedures (Sensitivity). With regard to recognition of relationships as derived from the Theory, students were expected to detect patterns and similarities in various concepts and utilize their prior knowledge to solve novel problems.

The teacher guided the students in constructing the basic concepts and provided learning experiences to apply such understanding in new situations. This was achieved through use of DTA implementation manual. Flexibility in reasoning is key for mathematical operations and logical assessment of the problem. The topic of the "mole" had several arithmetical problems that the student encountered in the course of learning. By use of DTA, the teacher provided the opportunity and learning experiences suitable for this to happen during chemistry instruction. Discovery Teaching Approach provided the opportunity for the learner to explore and interact with the environment in a way that facilitated development of the three Scientific Creativity abilities of Sensitivity, Recognition and Flexibility as implied in the Theory of Multiple intelligence. The study assumed that active participation of the learners in knowledge construction provided the opportunity for development of the abilities.

2.6.2 Okere's Model of Scientific Creativity

According to Okere (1996) as cited in Obote (2016), Scientific Creativity model has four main tenets of Sensitivity, Flexibility, Recognition and planning in the process of finding solutions to particular scientific problems. The model maps the psychological definitions of dimensions of Scientific Creativity into scientific meaning. On Sensitivity, it is asserted that the learner should be able to notice errors in calculations and formulae, as well as errors in experimental procedures. Recognition enables the learner to identify relationships, patterns and similarities among concepts and use them to further generate hypotheses and facts of ideas observed. Flexibility in reasoning enables learners to produce a variety of solutions even when they are not necessarily expected. Learners with ability to plan for scientific investigations should be able to take correct steps and measures in pursuit of a problem or experiment. These Scientific Creativity abilities are not independent of each other and thus a particular problem may require a multiple of these abilities to solve. The present study

keenly focused on Scientific Creativity abilities of Sensitivity to scientific problems, Recognition of relationships and patterns as well as Flexibility in reasoning, and how to influence the learning abilities during chemistry instruction in the classrooms.

In this study, students were expected to develop these scientific creativity abilities as they interacted with their environment, explored and constructed knowledge. Knowledge construction in the mole topic involved hypothesizing and creating ideas, carrying out various arithmetical operations and relating various formulae and similarities to solve new problems. These opportunities were provided through use of the DTA in Chemistry instruction.

Figure 1 shows the interactions of psychological definitions and scientific meanings of Scientific Creativity according to Okere's model of Scientific Creativity.

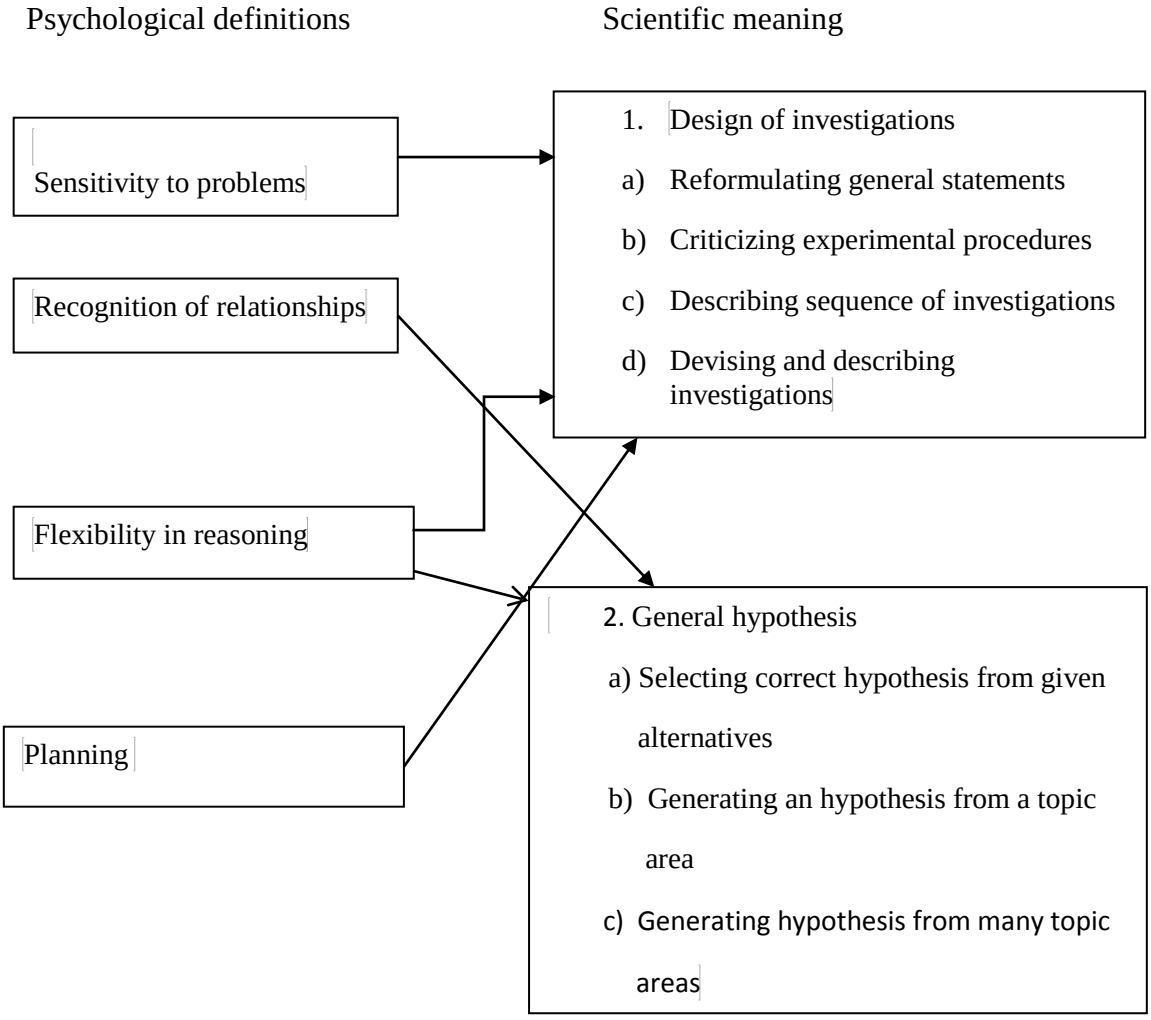

Figure 1: The Mapping of Psychological Definitions of Creativity on to Scientific Meanings (Okere, 1986).

The model in Figure 1 shows the mapping of psychological definitions of Scientific Creativity onto the scientific meanings. The model guided the development and adoption of the research tools.

2.7 Conceptual Framework

The conceptual framework is developed from the reviewed literature as the study sought to investigate the effect of Discovery Teaching Approach on development of Scientific Creativity abilities in chemistry amongst form three students. The teaching and learning of chemistry is influenced by various factors which include students' characteristics, teachers' characteristics, classroom environment and teaching approaches. Similar characteristics would influence the degree of enhancement of Scientific Creativity during chemistry instruction. This study sought to determine the effect of Discovery Teaching Approach (DTA) on the students' Scientific Creativity in chemistry. This was controlled by use of Traditional Teaching Approaches (TTA). For the present study, Discovery Teaching Approach was the independent variable. An independent variable is one that the researcher manipulates in order to determine its effect or influence on another variable, which is the dependent variable. Students' Scientific Creativity abilities of Sensitivity, Recognition and Flexibility are the dependent variables.

A dependent variable attempts to indicate the total influence arising from the effects of independent variable. It is the variable being observed or measured for changes that are thought to be caused by changes in the independent variable. Teachers' gender, training and experience as well as students' characteristic of school category have been identified as intervening variables. Intervening variables are those that are used to explain the relationship between two variables; the independent and the dependent but are not themselves explicitly studied, but may have an effect on the outcome of a research study, hence the need to control them. Intervening variables explain why or how the independent variable affects the dependent variable.

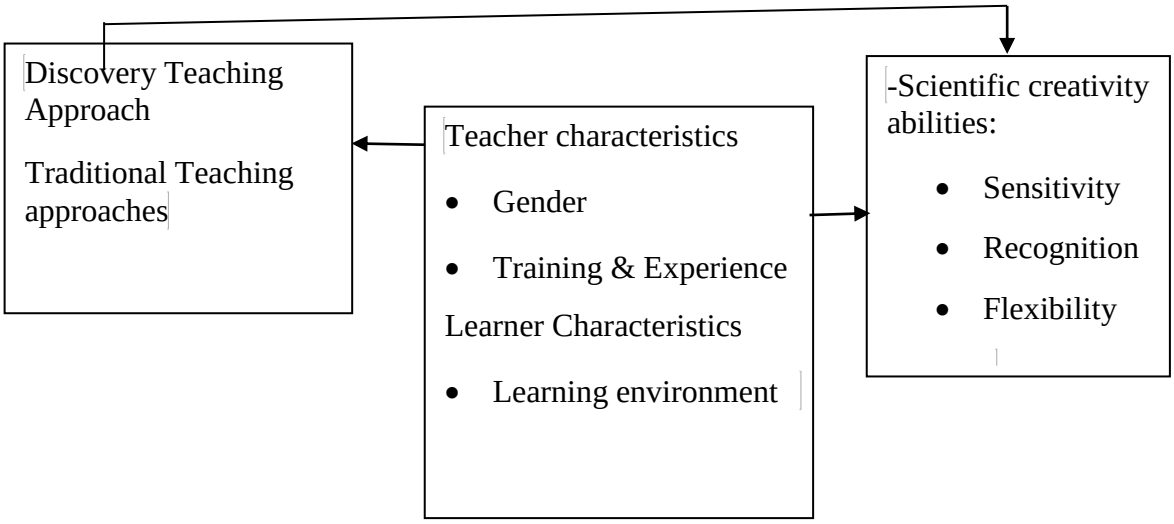

Figure 2: The Conceptual Framework for the Study

Figure 2 shows the conceptual frame work for the present study. Teacher's gender may influence perception of Scientific Creativity as a skill and how to focus on it during teaching. Teacher's experience and training may also determine the strategy adopted and how efficiently and effectively the strategy is applied. In order to control the teacher characteristics, the present study involved teachers who have at least three years of experience and at least a minimum qualification of a diploma in education and qualified to teach chemistry in secondary schools. The effect of the teachers' gender was also controlled by involving both female and male teachers in the study. In expression of creativity, girls focus on feelings and emotions and their responses are more descriptive and include more details (Sax, 2005). To eliminate the effect of gender a confounding variable on the results, the present study involved students from Girls' only Public Secondary Schools. The present study involved Public Secondary Schools in which entry behavior, resources and facilities are almost similar. This ruled out any major disparities as regards the learning environment.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Study Location

The study was based in Imenti North Sub-county in Meru County, Kenya. Meru County is in the Eastern region of Kenya. It borders Tharaka Nithi to the South, Laikipia to Northwest, and Isiolo to the North. Meru County is subdivided into eight Sub-Counties. Imenti North Sub-County borders Imenti Central to the South, Buuri East to the west, Tigania West to the North and Tharaka North to the South. Imenti North was selected because little or no information was known about the effect of DTA on Chemistry students' Scientific Creativity in Secondary schools in the Sub-County.

3.2 Research Design

The study used Quasi-experimental research design and in particular Solomon Four-Group Non-Equivalent Control Group Design. Quasi-experimental design uses naturally constituted groups such as classes in research. It allows the researcher to select a sample from the population without the random assignment of individual cases to comparison groups. Quasi-experimental design was appropriate for the present study because the research participants (students) would not be randomly assigned to experimental and control groups and the researcher worked with the existing intact classes. This is because once classes are constituted, they exist as intact groups. Solomon Four Group Non-Equivalent Control Group design is rigorous enough for experimental and quasi-experimental studies (Otiende, Barchok & Abura, 2013). Hence, the design was used to achieve four main purposes namely, to assess the effect of experimental treatment relative to control conditions, to assess the effect of pre-test relative to non-pre-test, to assess the interaction between pre-test and treatment conditions, and to assess the entry characteristics of the students in the groups before administration of the treatment.

Solomon Four Group design is the most rigorous design in quantitative studies since it uses two control groups in comparison to other experimental designs (Thayer & Martha, 2009). The design allows the researcher to make more complex assessment of the cause of changes in the dependent variable. The design provides the researcher confidence in the significance of the study results since it guards against both threats

of internal and external validity except those associated with interactions of selection and history, selection and maturation and selection and instrumentation (Fraenkel & Wallen, 2000). The non-equivalent group pre-test-post-test approach was used to understand the entry behavior of the students in the experimental and control groups (Githua & Mwangi, 2013). Four groups were involved in the study, comprising of experimental group 1 and 2 coded as E1 and E2 respectively, and control groups 1 and 2 coded as C1 and C2 respectively. Figure 3 shows Solomon Four Group Non-Equivalent Control Group design used in the study.

Group I (E1) ……O_1…….X……..O_2

_____

Group II (C1) ……..O_3……..O_4

_____

Group III (E2) ……X…….O_5

_____

Group IV (C2) ……..…….O_6

_____

Figure 3: Solomon Four Group, Non-Equivalent Control Group Design

Key:

X is the treatment where students were taught through Discovery Teaching Approach. O_1 and O_3 are pretest while O_2, O_4, O_5, O_6 are posttests.

Group I is the experimental group E1, which received the pretest, the treatment and the posttest. Group II is the control group C1, which received a pretest followed by the control condition (Traditional Teaching Approaches) and finally a posttest. Group III is the experimental group E2 that received treatment (X) and a posttest, it was not be pretested. Group IV is the control group C2 that received posttest only, while the line _____ shows use of non-equivalent groups

The pretests were used to determine whether the students had similar entry characteristics. Comparison between experimental group 1 and control group 1 was used to reveal any effect of pre-test. Post-test O5 determined effect of the treatment on the experimental group E2 and O6 ruled out any interaction between pretesting and treatment. The pretest and posttest were treated as normal tests that are administered to students. The control and experimental groups were from different schools to avoid interaction of subjects. The subjects were taught by their own teachers so that they are not aware of the experimentation.

3.3 The Mole

Topic of the Mole is taught at Form Three according to the Kenya Institute of Curriculum Development (KICD) secondary school Chemistry syllabus. Some of the specific objectives of this topic deal with conversions of mass to moles, moles to molarity, calculations of various amounts of substances, determination and writing of chemical equations as well as applying scientific laws to carry out calculations (KLB, 2011). The concepts of the topic cuts across the secondary school chemistry syllabus hence its understanding is key to the understanding of several other topics (Chang, 2003). Besides, Schmidt and Jigneus, (2003) posit that understanding the mole concept enables learners to understand stoichiometry which is the backbone of the rest of the chemistry. For this reason and that it involves working with many formulae, expressions and calculations, the topic was appropriate for the present study.

3.4 Target Population

The target population for the study was all students in Public Secondary Schools in Imenti North Sub County. The accessible population was composed of the form three students. The class was selected because the topic of the 'Mole: Chemical Formulae and Equations' is taught at this level. There are 39 public secondary schools of which 10 are Girls' secondary schools, 6 Boys' secondary schools and 23 co-educational. Form three students accounted for 4862 students according to the Sub-County Education Officer Imenti North Sub-county (2018).

3.5 Sampling Procedures and Sample Size

The participating schools were purposively sampled from a list of Girls' County Public Secondary Schools within Imenti North Sub-county. The basis of purposive sampling of the schools was possession of the desired characteristics such as being Girls' Only County Secondary Schools, class size of more than 40 students per stream, and well equipped science and Information communication technology (ICT) laboratories. Girls' only Secondary Schools participated in the study to eliminate the effect of gender on the results as a confounding variable since the level of creativity between boys and girls is different (Baer, 2008). Students from the sampled schools were assigned to experimental groups (E1 and E2) and control groups (C1 and C2). In schools with more than one stream, one of the streams was randomly selected by use

of simple random sampling for data analysis (Barchok, 2011). Table 1 shows the summary of the sample size.

Table 1: Number of Schools and Number of Respondents in each School

No. of Girls schools sampled		No. of respondents per group
1	C1	47
1	E1	46
1	C2	46
1	E2	47
Total 4		186

The sampled schools had average enrolments of 46 students per stream but the actual sample size for the study was 186 students.

3.6 Research Instruments

The Chemistry Creativity Test (CCT) developed by the researcher and the Chemistry Class Creativity Observation Schedule (CCCOS) adopted from Obote (2011) and Njue (2016), and modified by the researcher were used for data collection.

3.6.1 Chemistry Creativity Test (CCT)

Chemistry Creativity Test (CCT) was based on the topic "The Mole: Chemical formulae and equations" with items focusing on Sensitivity, Recognition and Flexibility. The instrument had three sections comprising of four structured items on Sensitivity, four structured items on Recognition and two structured items on Flexibility. Each of the sections was scored out of ten marks using a predetermined and moderated marking scheme that guided on the scores to be awarded on each test item. The total score for the Chemistry Creativity Test was 30 marks, and this was converted to a percentage for ease of handling. To effectively address each objective of the study, students' scores on Sensitivity, Recognition and Flexibility were also treated independently as raw scores and as percentages. Levels of Scientific Creativity were indicated as either very low, low, moderate or above average depending on the percentage marks scored in the test with respect to the preset marking scheme.

3.6.2 Chemistry Class Creativity Observation Schedule (CCCOS)

The Chemistry Class Creativity Observation Schedule **(**CCCOS) was designed to objectively collect qualitative information about students' behavioral responses that are indicative of Scientific Creativity in the course of learning. The schedule composed of fifteen items or arrays to assess the observable indicators of the three aspects of Scientific Creativity of Sensitivity, Recognition and Flexibility. The instrument was divided into three sections each of which contained five observable attributes of Sensitivity, Recognition or Flexibility. These observable attributes are labeled as arrays for the three aspects. The responses scored as arrays, were either verbal or nonverbal. The frequency of these responses was checked and recorded by ticking at intervals of five minutes, that is, 5^{th}, 10th, 15^{th} to 40^{th} minute, in the course of the chemistry lesson giving a possible total of eight ticks per array per student in the course of the lesson. In the course of the lesson, the check listing was done for each student in the class for each array at the time interval where it occurred.

To make it easy to observe and score for each learner, a sitting plan was established and each student assigned a number on the sitting plan sheet, which was then indicated on the observation sheet. This made it possible for the scoring to be done for each student conveniently. Each aspect of Scientific Creativity had a maximum of five arrays in CCCOS. The frequency of the occurrences of the Sensitivity arrays, Recognition arrays and Flexibility arrays was tallied at the end of the lesson. The possible total scores for Sensitivity, Recognition and Flexibility arrays were forty ticks each. This translated to a possible maximum of 120 ticks for the whole CCCOS. The frequency data for each Scientific Creativity aspect was analyzed independently according to the three objectives of the study. The total score of 120 was used to determine the overall Scientific Creativity level of the students.

3.7 Validity

Validity is that quality of data gathering instrument that enables it to measure what it is supposed to measure (Gay & Airasian, 2003). For the present study, a table of specifications was constructed to ensure that the items in the instruments were based on the context and content of the study. Face validity is the extent to which a test is viewed as covering the concept it purports to measure or the relevance of the test as it

appears to test the examinees (Holden, 2010). Content validity is the extent to which the items in a test assess the same content or how well the content material is sampled in the test (Doris, Marla, Susan, Lee & Shannon, 2003). Face and content validity of the instruments were determined by chemistry teachers who are examiners with the Kenya national Examinations council (KNEC) and university supervisors in Chuka University department of education, who are experts.

3.8 Reliability

According to Orodho (2004), reliability of instruments concerns the degree to which a particular measuring procedure gives similar results over a repeated trial. The reliability of the research instruments was determined using the KR-21. The two instruments, CCT and CCCOS were pilot tested on students in different schools in the neighboring Sub-county of Imenti South, who had similar characteristics. The piloting was done before commencement of the study. Kuder-Richardson Formula (KR-21) was used to estimate the reliability of CCT and CCCOS. A reliability coefficient of 0.7823 and 0.8214 were obtained for CCT and CCCOS respectively. According to Lance (2006), reliability coefficients above 0.7 are considered acceptable. Hence the reliability coefficients for CCT and CCCOS were accepted for the study.

3.9 Data Collection Procedure

The researcher sought clearance for the research from Chuka University Ethics committee. The researcher then applied for research permit from the National Council for Science Technology and Innovation (NACOSTI), in the ministry of Education. Upon receipt of the permit, the researcher personally presented himself with a copy of the permit to the Meru County Commissioner, then to the County Director of Education for introduction and notification. The researcher obtained permission and introduction letters form the above authorities with which he presented to the principals of the schools. The principals of the schools involved in the research were informed about the same. The researcher then inducted the teachers using the Discovery Teaching Approach (DTA) Teacher Training Manual for two days. Teaching was guided by the Discovery Teaching Approach Implementation Schedule, which the researcher introduced to the teachers.

Posttests were administered five weeks after the administration of the pretests. Pretests included CCT and CCCOS. CCT had three sections comprising of four structured items on sensitivity, four on Recognition and two structured items on flexibility. The test was administered as a normal opener test by the chemistry teachers. The teachers marked and scored the test normally and gave the results to the researcher. To ascertain the authenticity of the scores, the researcher sampled the marked scripts, and counterchecked the marking and scoring. The mean scores were calculated and data coded for analysis.

For CCCOS, the researcher organized with the teacher on a day to carry out the observation. Since the students were many and the test involved check listing for each student, a sitting plan was made in liaison with the subject teacher. Each student was assigned a number on the sitting plan sheet. The number was indicated on each student's observation sheet for easy tracking and transfer of data. On the material day, the researcher was introduced to the students as a lesson observer. This was just like the normal lesson observation by fellow teachers or by their supervisors as a requirement for the Teachers' Performance Appraisal and Development (TPAD) tool.

The researcher check listed the behavioural responses of Scientific Creativity exhibited by each learner in the course of the lesson. At the end of the lesson, the ticks were transferred to the observation sheet. The ticks for each array were tallied and recorded. The total ticks for each section was calculated and recorded. Each section gave a possible maximum of forty ticks and the whole test was scored out of the possible 120 ticks. Means were then calculated. The scores for each section were treated independently according to the three objectives of the study. The data collected was then coded for further statistical analysis.

The same procedure was repeated for the posttests. Students in experimental group E1 were exposed to a pretest, and then taught concepts on 'The mole' using the Discovery Teaching Approach (Treatment). They were then subjected to a posttest. The subjects in control group C1 were subjected to a pre-test, no treatment, but they were subjected to a post-test. Those in experimental group E2 were not subjected to a pre-test, but they were subjected to the treatment and to a posttest. Those in control

group C2 were not subjected to a pre-test or treatment, but were exposed to a post-test. After administration of the tests, students' responses were marked, scores recorded and their mean scores calculated.

3.10 Ethical Considerations

Ethics is a code of conduct or expected behavior while conducting a research (Sekaran and Bougie, 2009). Research ethics promote a variety of important moral and social values such as social responsibility, human rights, compliance with laws, honesty, and safety (David, 2015). For the present study, respondents were not forced or coerced to take part in the study. Consent for the students' participation in the study was sought from their teachers because they are not yet adults to consent by themselves. In all the schools involved, there was more than one stream. Therefore to avoid differential treatment of the form three students in the experimental groups, treatment was administered to all the streams but results from only one stream were used for data analysis. The test (CCT) was administered to the students by their teachers as part of the normal continuous assessment tests. This helped reduce any anxiety associated with tests and strangers in their classes.

3.11 Data Analysis

Data analysis refers to categorizing, ordering and summarizing of data to obtain answers to the research questions or hypotheses. Data was analyzed using both descriptive and inferential statistics. Descriptive statistics included means and standard deviations. Inferential statistics included t-test and one way analysis of variance (ANOVA). Analysis was performed using statistical package for social sciences (SPSS) computer package version 22.0. Hypotheses were tested at $\alpha=0.05$ level of significance.

Table 2 indicates how data related to respective hypotheses was analyzed.

Table 2: Summary of the Variables and Statistical Tests of the Study

Hypothesis	Independent variable	Dependent variable	Statistical test
$H_0$1: There is no statistical significant difference in sensitivity to chemistry problems between students subjected to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches.	Discovery Teaching Approach Traditional Teaching Approaches	Sensitivity to chemistry problems	Means t-test ANOVA
$H_0$2: There is no statistical significant difference in recognition of relationships between patterns, general scientific observations and scientific concepts in chemistry between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches.	Discovery teaching approach Traditional teaching approaches	Recognition of relationships between general observations and chemistry concepts	Means t-test ANOVA
$H_0$3: There is no statistically significant difference in flexibility in reasoning in chemistry between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches.	Discovery Teaching Approach Traditional Teaching Approaches	Flexibility in reasoning in chemistry	Means t-test ANOVA

CHAPTER FOUR

RESULTS PRESENTATION

4.1 Results of DTA on Students' Sensitivity, Recognition and Flexibility in Chemistry

This section shows data collected from the pretests on Sensitivity, Recognition and Flexibility. To determine the levels of Sensitivity, Recognition and Flexibility abilities in chemistry, students were asked to respond to items in Chemistry Creativity Test (CCT). CCT had three sections comprising of four structured questions on Sensitivity, four structured questions on Recognition and two structured questions on Flexibility. The questions were based on the topic of the 'Mole: Chemical Formulae and Equations'. Items in each section were scored out of ten marks. The total score for the whole CCT was thirty marks.

4.1.1 Results on Students' Sensitivity to Chemistry Problems

The first objective of the study sought to determine whether there was a statistical significant difference in Sensitivity to chemistry problems between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches. Students were asked to respond to items in Chemistry Creativity Test (CCT). The items were based on the topic of the Mole. Students were presented with problems that were wrongly worked out, solutions had errors or were fallacious. The students were expected to find the errors, mistakes and incorrect solutions presented, and work them out correctly.

In order to determine the students' Sensitivity to chemistry problems before exposure to Discovery Teaching Approach, pretest mean scores obtained from CCT and Sensitivity frequency data from CCCOS were analyzed for control group C1 and experimental group E1.

Table 3 shows the pretest mean scores on Sensitivity based on CCT.

Table 3: Pretest Mean Scores on Sensitivity to Chemistry Problems Based on CCT.

Group	n	Mean	Standard deviation
C1	47	1.51	0.233
E1	46	1.46	0 .193

Results in Table 3 shows that the mean score for the experimental group E1 was 1.46 and that of control group C1 was 1.51. The scores were out of ten. This shows that the mean scores for the two groups were different with the control group C1 having a higher mean score. In order to find out whether there was a significant difference in the pretest mean scores for the two groups, an independent t-test was carried out. The results are presented in Table 4.

Table 4: The independent t-test of Pretest Mean Scores on Sensitivity to Chemistry Problems Based on CCT

Test		t	df	p value
CCT	Equal variances assumed	0 .178	91	0.859
	Equal variances not assumed	0.179	88.303	0.859

Information in Table 4 reveal that there was no significant difference in the mean scores of the two groups t (91) = 0.178, p>0.05. The value for $t_{critical(1.662)} > t_{computed(0.178)}$. This is an indication that the mean scores for the two groups were the same. This implied that the level of students' Sensitivity to chemistry problems in the two groups was equivalent before exposure to the treatment, hence suitable for the study.

Table 5 shows the pretest Sensitivity frequency data based on CCCOS

Table 5: Analysis of Students' Sensitivity Frequencies in CCCOS before Exposure to DTA

Array	Behavioural reactions by learner in the course of the lesson exhibited as follows:	Frequency levels C1	E1
Sa1	Identifies errors or omissions in calculations	7.425	7.522
Sa2	Seeks clarity from the teacher/other learners	8.127	8.088
Sa3	Intrinsically takes notes during the lesson	10.319	10.087
Sa4	Offers alternatives to methods, and formulae.	12.106	12.000
Sa5	Positively critiques and redefines ideas	6.319	6.522
	Grand mean values	8.859	8.844

Key: Sa -Sensitivity Arrays,

Data presented in Table 5 shows the frequencies of students' observable reactions during the lesson before exposure to Discovery Teaching Approach. The total attainable maximum score was forty. Control group C1 had a frequency of 8.859 and experimental group E1 recorded frequency of 8.844 out of forty. The control and experimental groups registered almost the same mean frequencies indicating a possible similarity Sensitivity levels. Qualitative data from the Chemistry Classroom Creativity Observation schedule (CCCOS) was used to supplement the quantitative data collected by CCT. The qualitative data described the students' responses during the lesson so as to provide a qualitative understanding of Sensitivity, as an aspect Scientific Creativity in areas not explicitly captured in quantitative data.

Analysis of posttest was conducted based on students' mean scores on Sensitivity to chemistry problems.

Table 6 presents mean scores of the posttest results based on CCT.

Table 6: Posttest Mean Scores of Students' Sensitivity Based on CCT.

Group	n	Mean	Standard Deviation
C1	47	1.47	1.472
E1	46	3.37	1.936
C2	46	1.59	1.309
E2	47	2.91	1.705

Information in Table 6 shows the mean score for experimental group E1 was the highest at 3.37, followed by group E2 with a mean of 2.91. Control group C1 had a

mean of 1.47 and control group C2 a mean of 1.59. Experimental groups showed improved scores than the control groups. Sensitivity scores in experimental group E1 increased from 1.46 to 3.37 out of the possible maximum of ten marks in CCT. Experimental group E2 attained 2.91 out of 10 in CCT after the treatment. To determine whether the posttest means on Sensitivity were significantly different for the four groups, one way ANOVA was carried out. Results are as presented in Table 7.

Table 7: Analysis of Variance (ANOVA) of Posttest Mean Scores on Sensitivity to Chemistry Problems Based on CCT.

Source	Sum of squares	df	mean square	F	p value
Between groups	126.102	3	42.034	15.963	0.000
Within groups	479.231	182	2.663		
Total	650.333	185			

Results in Table 7 show that there was a significant difference between the means of the four groups, F (3,182) = 15.963, $p<0.05$. The value for $F_{critical(2.654)} < F_{computed(15.963)}$ indicating that the mean scores for the four groups were different. This implies that there was a significant difference on Sensitivity to chemistry problems for the four groups after exposure to Discovery Teaching Approach. This led to the rejection of the null hypothesis (HO_1), which stated that there was no statistical significant difference in Sensitivity to chemistry problems between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches. To find out which groups differed significantly, *Bonferroni Post Hoc* test of multiple comparisons was carried out. *Bonferroni test* was preferred for the present study because it controls for the overall rate hence the observed significance level is adjusted for the fact that multiple comparisons are being made. Results of the analysis are presented in Table 8.

Table 8: Comparisons of Posttest Mean Scores on Sensitivity to Chemistry Problems Based on CCT

(I) type of group	(J) type of Group	Mean Difference (I-J)	Std. Error	P value
C1	E1	-1.901(*)	0.337	0.000
	C2	-0.119	0.337	1.000
	E2	-1.447(*)	0.335	0.000
E1	C1	1.901(*)	0.337	0.000
	C2	1.783(*)	0.338	0.000
	E2	0.455	0.337	1.000
C2	C1	0.119	0.337	1.000
	E1	-1.783(*)	0.338	0.000
	E2	-1.328(*)	0.337	0.001
E2	C1	1.447(*)	0.335	0.000
	E1	-0.455	0.337	1.000
	C2	1.328(*)	0.337	0.001

*The mean difference is significant at the 0.05 level.

Information in Table 8 shows that the mean differences of groups C1 versus E1(1.901) and E2 (1.447) and C2 versus E1 (1.783) and E2 (1.328) were statistically significant since P<0.05. The difference between C1 and C2 (0.119) and E1 and E2 (0.455) is not statistically significant since p>0.05. Hence it can be concluded that DTA has a significant effect on students' Sensitivity to chemistry problems.

In order to determine the effect of DTA on students' Sensitivity to chemistry problems, frequency data from CCCOS was also analyzed. The mean score for each group was calculated.

Table 9 shows the analysis of students' Sensitivity frequencies from CCCOS after the treatment.

Table 9: Analysis of Students' Sensitivity Frequencies in CCCOS after the Treatment.

Array	Behavioural reactions by learner in the course of the lesson exhibited as follows:	Frequency levels			
		C1	E1	C2	E2
Sa1	Identifies errors or omissions in calculations	7.298	17.042	11.085	20.170
Sa2	Seeks clarity from the teacher/other learners	8.021	19.000	3.255	20.404
Sa3	Intrinsically takes notes during the lesson	11.128	19.085	11.362	20.064
Sa4	Offers alternatives to methods, and formulae.	11.085	20.106	10.085	19.872
Sa5	Positively critiques and redefines ideas	7.298	19.170	7.532	19.043
	Grand mean values	8.966	18.881	8.664	19.911

Key: Sa -Sensitivity Arrays

Data presented in Table 9 shows the frequencies of students' observable responses during the lesson after the exposure to DTA. The maximum possible frequency score was forty. Experimental groups recorded higher frequencies than control groups. Experimental group E1 had a frequency of 18.881 and experimental group E2 recorded a frequency of 19.911. Control groups C1 and C2 recorded 8.966 and 8.664 respectively. Sensitivity frequency data for the experimental groups was also higher than those of the control groups after the treatment. For experimental group E1, the frequencies increased from 8.844 to 18.881 out of the possible maximum score of forty. Experimental group E2 attained 19.911 out of 40 in CCCOS after the treatment. The qualitative data collected by Chemistry Classroom Creativity Observation Schedule (CCCOS) supplemented the quantitative data collected by CCT in highlighting the qualitative aspects of Scientific Creativity that could not be fully captured quantitatively. The data in CCCOS gave descriptions of the learners' reactions and activities during the lesson that provide an in-depth understanding of Sensitivity as an aspect of Scientific Creativity.

4.1.2 Results on Students' Recognition of Relationships between Patterns, General Scientific Observations and Scientific Concepts in Chemistry.

In order to assess the level of Recognition of relationships between general observations and chemistry concepts among students before the exposure to DTA, pretest scores obtained from CCT were analyzed for control group C1 and experimental group E1. Table 10 shows pretest mean scores on Recognition of relationships between general observations and chemistry concepts based on CCT.

Table 10: Pretest Mean Scores on Recognition of Relationships in Chemistry Based on CCT.

Group	n	Mean	Standard deviation
C1	47	3.38	0.412
E1	46	4.09	0.304

Information in Table 10 shows that the mean score for control group C1 and experimental group E1 were 3.38 and 4.09 respectively. This shows that the mean scores of the two groups are different with the experimental group having a higher mean score. To determine whether there was a statistical significant difference in the pretest means of the two groups, an independent t-test was carried out. Results are presented in Table 11

Table 11: The Independent t-test of Pretest Mean Scores on Students' Recognition Levels Based on CCT

	t	df	p value
Equal variances assumed	1.370	91	0.174
Equal variances not assumed	1.374	84.239	0.173

Results in Table 11 show that there was no significant difference in the mean scores of the two groups t (91) =1.370, p>0.05. The value of $t_{critical(1.662)} > t_{computed(1.370)}$, indicating that the means of the two groups were not different. This implies that the students' level of Recognition of relationships between general observations and chemistry concepts in the two groups was equal before exposure to the treatment. Thus the groups were suitable for the study. The frequency data from CCCOS was also analyzed. Results are presented in table 12.

Table 12: Analysis of Students' Recognition Frequencies in CCCOS before Exposure to DTA

Array	Behavioural reactions by learner in the course of the lesson exhibited as follows:	Frequency levels C1	E1
Ra1	Recalls facts, ideas, formulae and topics studied earlier	3.106	3.217
Ra2	Identifies patterns, relationships and similarities	4.213	4.109
Ra3	Associates earlier experiences with the current	6.340	6.522
Ra4	Responds by Citing related ideas from other topics	5.426	5.891
Ra5	Generalizes patterns, variations and formulae	7.128	7.761
Total		5.243	5.500

Key: Ra -Recognition Arrays,

Data presented in Table 12 shows the frequencies of students' observable reactions during the lesson before exposure to DTA. Control group C1 had a mean frequency of 5.243 and experimental group E1 recorded frequency of 5.5 out of the possible maximum frequency scores of forty. Thus control and experimental groups registered almost the same mean frequencies before the treatment indicating similarity in Recognition levels before the treatment.

For purposes of determining the effect of Discovery Teaching Approach on students' Recognition of relationships between patterns, general observations and scientific concepts in chemistry after the treatment, Recognition mean scores obtained from CCT after exposure to DTA were analyzed. Mean score for each group was calculated.

Figure 4 shows the posttest mean scores on levels of Recognition of relationships in chemistry based on CCT.

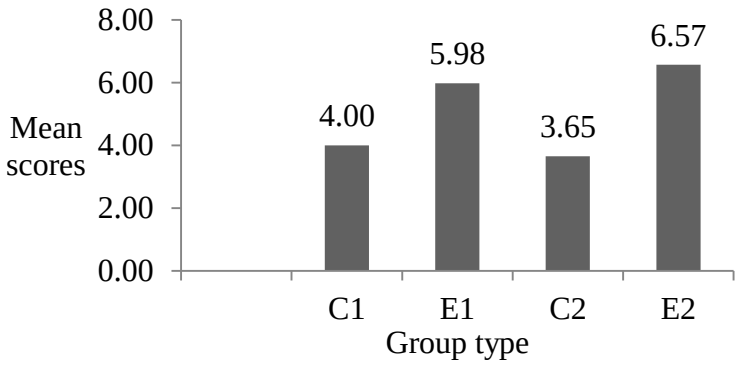

Figure 4: Posttest Mean Scores on Recognition Based on CCT

Results in Figure 4 show that the mean score for experimental group E2 was the highest at 6.574 followed by experimental group E1 at 5.978. Control group C1 had a mean of 4.0 and control group C2 had 3.652. To find out whether the means on Recognition of relationships in chemistry were significantly different for the four groups, one way ANOVA was conducted and results were as presented in Table 13.

Table 13: Analysis of Variance (ANOVA) of Posttest Mean Scores on Recognition of Relationships Based on CCT.

Source	Sum of Squares	df	Mean Square	F	P value
Between Groups	290.560	3	96.853	19.875	0.000
Within Groups	886.902	182	4.873		
Total	1177.462	185			

Results in Table 13 show that there was a significant difference between the means of the four groups, F 3(182) = 19.875 $p< 0.05$. $F_{critical(2.654)} < F_{computed(19.875)}$ which shows that the means of the four groups were different. Therefore, the null hypothesis (HO_2) which stated that there is no statistical significant difference in Recognition of relationships between patterns, general scientific observations and scientific concepts in chemistry between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches is rejected. This implies that there was a significant difference on Sensitivity to chemistry problems for the four groups. To investigate which groups showed significant difference, *Bonferroni Post Hoc* test of multiple comparisons was carried out. Results are presented in Table 14.

Table 14: Comparisons of Posttest Scores on Recognition of Relationships in Chemistry Based on CCT.

(I)type of Group	(J)type of Group	Mean Difference(I-J)	Std. Error	P value
C1	E1	-1.978*	0.458	0.000
	C2	0.348	0.458	1.000
	E2	-2.574*	0.455	0.000
E1	C1	1.978*	0.458	0.000
	C2	2.326*	0.460	0.000
	E2	-0.596	0.458	1.000
C2	C1	-0.348	0.458	1.000
	E1	-2.326*	0.460	0.000
	E2	-2.922*	0.458	0.000
E2	C1	2.574*	0.455	0.000
	E1	0.596	0.458	1.000
	C2	2.922*	0.458	0.000

*The mean difference is significant at 0.05 level.

Results in table 14 show that the mean differences of groups C1 versus E1 (1.978) and E2 (2.574) and C2 versus E1 (2.326) and E2 (2.922) were statistically significant since $P<0.05$. The difference between C1 and C2 (0.348) and E1 and E2 (0.596) is not statistically significant since $P>0.05$. Hence it is concluded that DTA has a significant effect on students' recognition of relationships.

Data frequencies obtained from CCCOS was also analyzed and results presented in Table 15.

Table 15: Analysis of Students' Recognition Frequencies Data in CCCOS after the Treatment.

Array	Behavioural reactions by learner in the course of the lesson exhibited as follows:	Frequency levels			
		C1	E1	C2	E2
Ra1	Recalls facts, ideas, formulae and topics studied earlier	4.128	14.936	5.128	16.553
Ra2	Identifies patterns, relationships and similarities	6.213	14.106	7.234	18.361
Ra3	Associates earlier experiences with the current	5.340	15.851	8.085	16.106
Ra4	Responds by Citing related ideas from other topics	7.298	16.064	5.978	14.851
Ra5	Generalizes patterns, variations and formulae	6.340	14.063	6.319	16.978
	Grand mean values	5.864	15.004	6.549	16.569

Key: Ra-Recognition Arrays

Data presented in Table 15 indicates the frequencies of students' observable responses during the lesson after the exposure to DTA. Experimental groups recorded higher frequencies than control groups. Experimental group E1 had a frequency of 15.004 and experimental group E2 recorded a frequency of 16.569. Control groups C1 and C2 recorded 5.864 and 6.549 respectively. This was out of the possible maximum frequency scores of forty. The qualitative data collected by Chemistry Classroom Creativity Observation Schedule (CCCOS) supplemented the quantitative data collected by CCT in highlighting the qualitative aspects of Scientific Creativity that could not be fully captured quantitatively. The data in CCCOS gave descriptions of the learners' reactions and activities during the lesson that provide an in-depth understanding of Recognition as an aspect of Scientific Creativity.

4.1.3 Results on Students' Flexibility in Reasoning in Chemistry.

In order to establish the level of Flexibility in reasoning in chemistry among the students before the exposure to Discovery Teaching Approach, pretest mean scores obtained from CCT were analyzed for control group C1 and experimental group E1.

Table 16 shows the pretest mean scores on Flexibility in reasoning based on Chemistry Creativity Test (CCT).

Table 16: Pretest Mean Scores on Flexibility in Reasoning Based on CCT

Group	n	Mean	Standard deviation
C1	47	0.30	0.587
E1	46	0.24	0.639

Data in Table 16 show that the mean score for the control group C1 is 0.30 and for the experimental group E1 is 0.24. This indicates that the mean scores of the two groups are different. In order to establish whether there was a significant difference between the means of the two groups, an independent t-test was conducted. Results are presented in Table 17.

Table 17: The t-test of Pretest Mean Scores on Flexibility in Reasoning Based on CCT

	t	df	p value
Equal variances assumed	0.462	91	0.645
Equal variances not assumed	0.462	89.973	0.645

Results in Table 17 show that there was no significant difference in the mean scores of the two groups t (91) = 0.462, p>0.05. The value of $t_{critical(1.662)} > t_{calculated(0.462)}$ which implies that the means for the two groups were the same. This is an indication that the level of Flexibility in reasoning for the two groups was equal before exposure to the treatment. This made the groups ideal for the present study.

Analysis was conducted on frequency data on Flexibility arrays collected by CCCOS. The results are presented in the Table 18.

Table 18: Analysis of Students' Flexibility Frequencies in CCCOS before Exposure to DTA

Array	Behavioural reactions by learner in the course of the lesson exhibited as follows:	Frequency levels C1	E1
Fa1	Tries to modify other learners' ideas, building on them	5.234	5.521
Fa2	Suggests alternatives to solve problems in class	2.419	2.217
Fa3	Making attempts despite several failures	3.553	3.391
Fa4	Consults other learners or teachers when stuck	6.149	7.348
Fa5	Explains to others what he/she is doing on B/board	4.745	6.109
	Grand mean values	4.366	4.917

Key: Fa -Flexibility Arrays.

Data presented in Table 18 shows the frequencies of students' observable Flexibility reactions during the lesson before exposure to DTA. Control group C1 had a mean frequency of 5.243 and experimental group E1 recorded mean frequency of 5.5. The control and experimental groups registered almost the same mean frequencies before the treatment indicating a possible similarity in Flexibility before the treatment. This made them suitable for the study.

In order to determine the effect of Discovery Teaching Approach on students' Flexibility in reasoning in chemistry after treatment, Flexibility posttest scores obtained from CCT were analyzed. The Mean for each group was calculated.

Figure 5 shows the posttest mean scores on levels of Flexibility in reasoning in chemistry based on CCT.

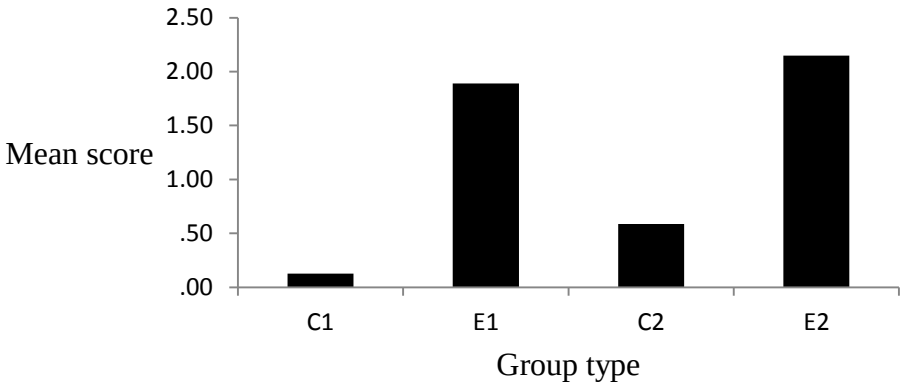

Figure 4: Posttest Mean Scores on Flexibility in Reasoning in Chemistry Based on CCT

Results in Figure 5 show that the mean score for experimental group E2 was the highest at 2.15 followed by experimental group E1 with 1.89. Control group C1 had a mean of 0.13 and control group C2 had 0.59. To find out whether the means on Flexibility in reasoning in chemistry were significantly different for the four groups, one way analysis of variance (ANOVA) was carried out and results were as presented in Table 19.

Table 19: Analysis of Variance (ANOVA) of Posttest Results on Flexibility in Reasoning in Based on CCT.

Source	Sum of Squares	df	Mean Square	F	P value
Between Groups	135.614	3	45.205	18.170	0.000
Within Groups	452.800	182	2.488		
Total	588.414	185			

Results in Table 19 show that there was a significant difference between the means of the four groups, F 3(182) = 18.170 $p< 0.05$. The value of $F_{critical\ (2.654)}< F_{computed(18.170)}$ indicating a difference in the means of the four groups. Therefore, the null hypothesis (HO_3) which stated that there is no significant difference in Flexibility in reasoning in Chemistry between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches is rejected. This implies that there was a significant difference on Flexibility in reasoning in chemistry for the four groups. To investigate which groups showed significant difference, *Bonferroni Post Hoc* test of multiple comparisons was carried out. Results are presented in Table 20

Table 20: Comparisons of Groups' Posttest Results on Flexibility Based on CCT.

(I) type of Group	(J) type of Group	Mean Difference (I-J)	Std. Error	P value
C1	E1	-1.764*	0.327	0.000
	C2	-.459	0.327	0.972
	E2	-2.021*	0.325	0.000
E1	C1	1.764*	0.327	0.000
	C2	1.304*	0.329	0.001
	E2	-0.258	0.327	1.000
C2	C1	0.459	0.327	0.972
	E1	-1.304*	0.329	0.001
	E2	-1.562*	0.327	0.000
E2	C1	2.021*	0.325	0.000
	E1	0.258	0.327	1.000
	C2	1.562*	0.327	0.000

*. The mean difference is significant at the 0.05 level.

Results in Table 20 show that the mean scores of groups C1 versus E1 (1.764) and E2 (2.021) and C2 versus E1 (1.304) and E2 (1.562) were statistically significant since $P<0.05$. The difference between C1 and C2 (0.459) and E1 and E2 (0.258) is not statistically significant since $p>0.05$. Therefore, it can be concluded that DTA has a significant effect on students' Flexibility in reasoning.

Analysis was also conducted on the frequency data collected on Flexibility in reasoning by use of Chemistry Class Creativity Observation Schedule (CCCOS). Results are shown in Table 21

Table 21: Analysis of Students' Results in CCCOS after the Treatment.

Array	Behavioural reactions by learner in the course of the lesson exhibited as follows:	Frequency levels C1	E1	C2	E2
Fa1	Tries to modify other learners' ideas, building on them	6.149	16.702	3.255	16.000
Fa2	Suggests alternatives to solve problems in class	7.234	16.021	6.553	17.043
Fa3	Making attempts despite several failures	3.255	14.319	8.043	19.000
Fa4	Consults other learners or teachers when stuck	5.745	12.787	6.085	17.043
Fa5	Explains to others what he/she is doing to on B/board	3.149	13.910	4.213	16.553
	Grand mean values	5.106	14.748	5.629	17.128

Key: Fa -Flexibility Arrays

Data presented in Table 21 indicates the frequencies of students' observable responses during the lesson after the exposure to Discovery Teaching Approach. Experimental groups recorded higher frequencies than control groups. Experimental group E1 had a frequency of 14.748 and experimental group E2 recorded a frequency of 17.128. Control groups C1 and C2 recorded 5.106 and 5.629 respectively. The scores were out of the possible maximum frequency score of forty. The qualitative data collected by Chemistry Classroom Creativity Observation schedule (CCCOS) supplemented the quantitative data collected by CCT in highlighting the qualitative aspects of Flexibility in reasoning that could not be fully captured quantitatively. The data in CCCOS gave descriptions of the learners' reactions and activities during the lesson that provide an in-depth understanding of Flexibility in reasoning as an aspect of Scientific Creativity.

4.1.4 Average Scientific Creativity in Chemistry

In order to establish the overall levels of the students' Scientific Creativity in chemistry before the treatment, the pretest mean scores for Sensitivity, Recognition and Flexibility were summarized. The average pretest mean scores for Sensitivity, Recognition and Flexibility are presented in Table 22.

Table 22: Overall Scientific Creativity Pretest and posttest Mean Scores Based on CCT

Ability	Group	n	Pretest Mean	Posttest mean	Deviation
sensitivity	C1	47	1.51	1.470	-0.040
	E1	46	1.46	3.370	+1.910
Average			1.49	2.330	+0.845
Recognition	C1	47	3.38	4.000	+0.620
	E1	46	4.09	5.798	+1.708
Average			3.74	5.043	+1.308
Flexibility	C1	47	0.30	0.130	-0.170
	E1	46	0.24	1.890	+1.650
Average			0.27	1.190	+0.920
Grand mean			1.83	2.854	+1.024

Information in Table 22 indicates that the mean for overall Scientific Creativity for all groups before and after the treatment. The data shows a general increase in the means for the experimental groups after exposure to Discovery Teaching Approach.

Sensitivity improves by 1.91, Recognition improves by 1.708 and Flexibility improves by 0.92. The overall scientific creativity improved from 1.83 to 2.854, indicating a positive deviation of 1.024. The mean score for each Scientific Creativity ability was out of ten and the total mean was out of thirty. After the exposure to Discovery Teaching Approach, the mean scores for Scientific Creativity based on CCT were determined.

The posttest mean scores were higher than the pretest mean scores. The information is presented in Table 23.

Table 23: Posttest Scientific Creativity Results Based on CCT.

Indicator	Group	n	Mean
Sensitivity	C1	47	1.470
	E1	46	3.370
	C2	47	1.570
	E2	46	2.910
Average			2.330
Recognition	C1	47	4.000
	E1	46	5.978
	C2	47	3.652
	E2	46	6.574
Average			5.043
Flexibility	C1	47	0.130
	E1	46	1.890
	C2	47	0.590
	E2	46	2.150
Average			1.190
Total mean			8.563

Information in Table 23 shows that the total mean for overall Scientific Creativity for all groups was 8.563 out of the possible maximum of 30. This indicates an increase in the mean scores for Scientific Creativity. The mean scores for experimental groups E1 and E2 were higher than those for control group C1 and C2 for Sensitivity, Recognition and Flexibility.

Summary frequency data for Scientific Creativity based on CCCOS was also calculated. The results are presented in Table 24.

Table 24: Pretest Scientific Creativity Results Based on CCCOS

Ability	Group	n	Mean
Sensitivity	C1	47	8.859
	E1	46	8.844
Average			8.852
Recognition	C1	47	5.243
	E1	46	5.500
Average			5.372
Flexibility	C1	47	4.366
	E1	46	4.917
Average			4.642
Total mean			18.866

Table 24 presents the summary frequency data on Scientific Creativity based on CCCOS. The average Scientific Creativity mean score is 18.866 out the possible maximum score of one hundred and twenty. Each of the abilities was scored out of possible maximum of forty. The results on Sensitivity, Recognition and Flexibility from CCCOS after use of Discovery Teaching Approach were also averaged. The results are presented in Table 25.

Table 25: Posttest Scientific Creativity Results Based on CCCOS

Ability	Group	n	Mean
Sensitivity	C1	47	8.966
	E1	46	18.881
	C2	47	8.664
	E2	46	19.911
Average			14.105
Recognition	C1	47	5.864
	E1	46	15.004
	C2	47	6.549
	E2	46	16.569
Average			10.997
Flexibility	C1	47	5.629
	E1	46	14.748
	C2	47	5.629
	E2	46	17.128
Average			10.783
Total mean			35.885

Information in Table 25 shows the mean overall scientific creativity after exposure to Discovery Teaching Approach. The total mean for all groups is 35.8855 out of a possible maximum score of 120. It is also evident that the experimental groups recorded higher Scientific Creativity scores than the control groups.

CHAPTER FIVE
RESULTS DISCUSSION

5.1 Discussion of the Results on Sensitivity to Chemistry Problems.

The first objective of the study was to investigate the effect of Discovery Teaching Approach on students' Sensitivity to chemistry problems. Results of the study have shown that there was a statistical significant difference in Sensitivity to chemistry problems between students taught by use of Discovery Teaching Approach and those taught using Traditional Teaching Approaches. Experimental groups showed improved scores than the control groups. Sensitivity scores in experimental group E1 increased from 1.46 to 3.37 out of the possible maximum of ten marks in CCT. Frequency data for the experimental groups was also higher than those of the control groups after the treatment. For experimental group E1, the frequencies increased from 8.844 to 18.881 out of the possible maximum score of forty. Experimental group E2 attained 2.91 out of 10 in CCT and 19.911 out of 40 in CCCOS respectively after the treatment. The increase in performance in CCT and the CCCOS indicates that Discovery Teaching Approach enhances Sensitivity to chemistry problems than Traditional Teaching Approaches. This implies that Discovery Teaching Approach is more effective than Traditional Teaching Approaches in enhancing students' Sensitivity to chemistry problems.

These findings are consistent with Safavi (2007), who studied methods and techniques of teaching in Tehran and reported that teaching by discovery enhances secondary school students' ability to specify the desired science problems, consider possible solutions, question existing solutions and procedures and apply the results to new situations. This implies that Discovery Teaching Approach enhances Sensitivity in science. The results are also in agreement with Yong, sang, Jung and Ji (2009), who investigated exercises for cognitive elements for design creativity among university students in Korea and found out that teaching by discovery enhanced Sensitivity in solving science problems.

5.2 Discussion of the Results on Recognition of Relationships between Patterns, General Scientific Observations and Scientific Concepts in Chemistry.

The second objective of the study was to determine the effect of Discovery Teaching Approach on students' Recognition of relationships between patterns, general observations and scientific concepts in chemistry. The results of this study have shown that there was a statistical significant difference in Recognition of relationships between patterns, general observations and scientific concepts in chemistry between students taught by use of Discovery Teaching Approach and those taught using Traditional Teaching Approaches. Experimental groups recorded higher scores than control groups. In CCT, experimental group E1 scores increased from 4.09 to 5.978 out of the possible maximum score of ten. Frequency data for experimental group E1 in CCCOS also improved from 5.5 to 15.004 out possible maximum score of forty. Experimental group E2 achieved 6.574 out of ten in CCT and 16.569 out of forty in CCCOS respectively. The increase in performance could be attributed to the treatment, showing that Discovery Teaching Approach enhances Recognition of relationships in chemistry amongst students. This implies that Discovery Teaching Approach is more effective in enhancing students' Recognition of relationships between patterns, general observations and scientific concepts in chemistry than Traditional Teaching Approaches.

These findings are consistent with Hodgkinson et al, (2008) who studied intuition as a fundamental bridging construct in the behavioural sciences in Britain and reported that Discovery Teaching Approach promotes pattern Recognition which is important in predicting possibilities in scientific problems. The findings also corroborate those of Cheng (2011) who investigated infusion of creativity in design amongst high school students in Indonesia and concluded that Discovery Teaching Approach nurtures students' ability to make connections between scientific observations and trends, and how to use them to formulate and test hypotheses and make conclusions on newer problems. The findings are also in agreement with Otiende, Barchok and Abura (2013) in a related study in Kenya. The researchers studied the effect of discovery method on secondary school students of physics and found out that use of discovery experimental teaching method increases students' Recognition of relationships, which enables the learners to form correct concepts. It is however,

established from the data in Figure 5 and Table 14 that the level of Recognition of relationships is generally low amongst the students.

5.3 Discussion of the results on Flexibility in Reasoning in Chemistry.

The third objective of the present study was to investigate the effect of Discovery Teaching Approach on students' Flexibility in reasoning in chemistry. The results of study have shown that there was a statistical significant difference in Flexibility in reasoning in chemistry between students taught by use of Discovery Teaching Approach and those taught using Traditional Teaching Approaches. Student performance for experimental groups was higher than that of the control groups. Students' scores in CCT increased from 0.24 to 1.89 for experimental group E1 as experimental group E2 attained 2.15 out of the possible maximum score of ten. Frequency data from CCCOS also increased from 4.917 to 14.748 for the experimental group E1. Experimental group E2 scored a mean of 17.128 out of the possible maximum score of forty. This increase in Flexibility in reasoning in the experimental groups after the treatment showed that Discovery Teaching Approach enhances Flexibility in reasoning in chemistry amongst students. This thus implies that Discovery Teaching Approach is more effective in enhancing students' Flexibility in reasoning in chemistry than Traditional Teaching Approaches.

The findings of the present study are in agreement with Ali (2013) who studied effect of discovery learning on reinforcing the creative thinking in sixth grade students in Iran and reported that use of Discovery Teaching Approach leads to increase in Flexibility in reasoning amongst the students. The findings are also in agreement with those of Gholamian, (2013). This researcher studied the effect of guided discovery learning approach on reinforcing the creative thinking of sixth grade girl students in Tehran and reported that teaching by discovery is significant in developing Flexibility in reasoning among science students. Kennet, Levy, Kennet, Stanley, Faust and Havlin (2018) also studied the Flexibility of thought in high creative individuals represented by percolation analysis amongst pensilvania university students in the United States of America and found that teaching by discovery improved learners' Flexibility of thought. This is also consistent with Smith and Ward (2012), who studied cognition and the creation of ideas and concluded that learning that involves

exploration, enhances one's ability to break mental fixations when solving a problem allowing for mental flexibility. Otiende, Barchok and Abura (2013), in a related study on the effect of discovery method on achievement in secondary school students of physics also posit that discovery teaching increases learners' Flexibility in reasoning which helps them correct any existing misconceptions and solve problems broadly.

Experimental groups E1 and E2 attained scores of 1.89 and 2.15 out of ten in CCT and 14.748 and 17.128 out of 40 in CCCOS. These figures show that the overall Flexibility level amongst students is generally low. This is so due to the low scores by the experimental groups. The findings partly corroborates those of Ndeke (2003), who studied the effect of knowledge and learning opportunities on Scientific Creativity amongst form three biology students in Nakuru Sub-county and found out that Flexibility aspect of Scientific Creativity is better performed by most students than the other aspects. The results from CCT also indicate possession of low levels of Flexibility in reasoning among chemistry students. This is evident from the low mean scores obtained by the learners in CCT.

5.4 Discussion of the Results Average Scientific Creativity in Chemistry.

Summary results deduced form the results of the three objectives of the study indicate that there is a statistical significant difference in the overall Scientific Creativity in chemistry between students taught using Discovery Teaching Approach and those taught using Traditional Teaching Approaches. This implies that teaching by Discovery Teaching Approach is more effective in enhancing Scientific Creativity amongst students in chemistry than Traditional Teaching Approaches. The summary frequency data from CCCOS after treatment were higher than before treatment. Pretest CCCOS overall data frequency was 18.866 while the overall posttest CCCOS overall frequency data increased to 35.885 out of the possible maximum score of 120. There was a positive improvement by 17.019.

Experimental groups E1 and E2 recorded average data frequencies of 34.080 while control groups C1 and C2 recorded average of 13.767. Higher frequencies of overall Scientific Creativity in experimental groups than in control groups, indicates that use of Discovery Teaching Approach enhances and increases Scientific Creativity

amongst secondary school chemistry students. The study findings indicate that use of Discovery Teaching Approach is more effective in enhancing Scientific Creativity than use of Traditional Teaching Approaches.

These summary findings are consistent with Rahman (2017). Rahman studied the use of discovery learning to encourage creative thinking in physics students of Khairun university of Ternate and reported that discovery approach enhances students' Scientific Creativity. The findings also similar to those of Riandari, Susanti and Suratmi (2018), who investigated the influence of application of Discovery Teaching Approach to the higher order thinking skills in high school students of Indonesia and found out that use of Discovery Teaching Approach enhances students' Scientific Creativity among science students. The findings are further corroborated by Longo (2010) that discovery learning is recommended in the instruction of science because it inculcates Scientific Creativity.

The findings are also in agreement with those of Otiende, Barchok and Abura (2013) in a related study. They investigated the effect of discovery experimental method on secondary school physics students' achievement in Kenya and reported that use of discovery experimental method increases students' Scientific Creativity levels. Scientific Creativity is nurtured through discovery teaching. This is because discovery allows learners to make scientific observations, formulate and test hypothesis, investigate and make conclusions individually (Cheng, 2011). This also consistent with Ali (2013) that teaching by discovery increases Scientific Creativity among students as further corroborated by Kind and Kind (2007) that learning by discovery enhances Scientific Creativity in science.

Discovery Teaching Approach provided the learners with an opportunity to generate knowledge by exploration of the learning environment by the learners. By discovery, learners are faced with real chemistry problems to solve with the varying levels of guidance by the teacher, hence getting a chance to develop creativity skills. The learning environment should be such that it arouses the learners' interests and allows them to be active participants. In agreement with this, Cheng (2004) carried out a study on developing learning activities that would foster creativity abilities amongst

science students in Hong Kong and found out that using open discovery approach could foster students' Scientific Creativity abilities.

It was also found out that the general Scientific Creativity levels were low. This is evident from the low scores of 8.563 out of thirty in CCT and 35.8855 out of 120 in CCCOS. This is consistent with Ndeke, (2003) and Ndeke, Okere and Keraro, (2015). The researchers investigated the secondary school biology teachers' perceptions of Scientific Creativity in Kenya and partly reported that the general level of Scientific Creativity among students of biology is low. This makes teaching of Scientific Creativity an important focus of science education. Adoption of appropriate teaching approaches would enhance Scientific Creativity amongst learners.

CHAPTER SIX
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

The first objective of the study was to investigate the effect of Discovery Teaching Approach on students' Sensitivity to chemistry problems. The findings of the study showed that there was a statistical significant difference in Sensitivity to chemistry problems between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches. The results showed that the experimental group outperformed the control group in CCT. The experimental group also recorded higher frequencies in CCCOS than the control group. It was thus concluded that Discovery Teaching Approach is more effective in enhancing Sensitivity to chemistry problems than Traditional Teaching Approaches. However, the results also indicated that the overall level of Sensitivity among the students was generally low.

The second objective was to determine the effect of Discovery Teaching Approach on students' Recognition of relationships between patterns, general scientific observations and scientific concepts in chemistry. The findings of the study showed a statistical significant difference in Recognition of relationships between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches. The experimental group performed better than the control group in CCT. The experimental group also recorded higher Recognition frequencies in CCCOS than the control group. The conclusion was that Discovery Teaching Approach is more effective in enhancing Recognition of relationships between patterns, general observations and the scientific concepts among the students of chemistry than Traditional Teaching Approaches. It was also found out that though teaching by Discovery Teaching Approach enhanced students' recognition of Relationships in chemistry, the overall level of Recognition among the students was generally low.

The third objective of the study was to investigate the effect of Discovery Teaching Approach on students' Flexibility in reasoning in chemistry. The findings of the study showed a statistical significant difference in Flexibility in reasoning between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches. The experimental group outperformed the control group in CCT.

Experimental group also recorded higher Flexibility frequencies in CCCOS than control group. It was therefore concluded that Discovery Teaching Approach is more effective in enhancing Flexibility in reasoning among students of chemistry than Traditional Teaching Approaches.

Findings on the overall Scientific Creativity, showed that Discovery Teaching Approach enhances Scientific Creativity among the students of chemistry than Traditional Teaching Approaches. The average performance of the experimental groups was higher than that of the control groups in both CCT and CCCOS. However, it was also found out that the general level of overall Scientific Creativity amongst the students of chemistry was low.

6.2 Conclusion

Students' exposure to Discovery Teaching Approach improved the acquisition of Scientific Creativity ability of Sensitivity. Therefore, incorporation of Discovery Teaching Approach in Chemistry instruction in secondary schools enhanced meaningful learning and better acquisition of skills by students in comparison to use of common Traditional Teaching Approaches. Thus, based on the first objective of the study that aimed at investigating the effect of Discovery Teaching Approach on students' Sensitivity to chemistry problems, it is concluded that Discovery Teaching Approach enhances Sensitivity to chemistry problems.

Results of the study indicated that Discovery Teaching Approach is beneficial in improving Recognition of relationships between patterns, general scientific observations and concepts in chemistry. This has the implication that Discovery Teaching Approach in teaching of chemistry in secondary schools enhanced acquisition of scientific skills and abilities in comparison to Traditional Teaching Approaches. This is because Discovery Teaching Approach provides a rich environment for learners to explore and interact with hence developing the requisite skills. Therefore, there is a difference in Recognition of relationships between students exposed to Discovery Teaching Approach and those exposed to Traditional Teaching Approaches.

Exposure of students to Discovery Teaching Approach enhanced the acquisition of Flexibility in reasoning. This implied that use of Discovery Teaching Approach in teaching of chemistry provided enhanced learning experiences for better acquisition of scientific skills by students in comparison to use of Traditional Teaching Approaches. Thus, based on the third objective of the study that aimed at investigating the effect of Discovery Teaching Approach on students' Flexibility in reasoning in chemistry, it is concluded that Discovery Teaching Approach enhances Flexibility in reasoning.

Use of Discovery Teaching Approach in chemistry teaching increased the overall Scientific Creativity levels among the students than use of Traditional Teaching Approaches. Discovery Teaching Approach produces higher levels of Scientific Creativity than use of Traditional Teaching Approaches, due to the fact that students explore, discover and construct knowledge and skills in Discovery Teaching Approach hence actively interacting with their learning environment which increases their overall Scientific Creativity levels. Use of Discovery Teaching Approach in chemistry instruction increases Scientific Creativity than use of Traditional Teaching Approaches.

6.3 Recommendations

Based on the findings of this study, the following recommendations were made:

i. Chemistry teachers should embrace use of Discovery Teaching Approach as an instructional approach of enhancing students' Scientific Creativity in the course of learning the subject. This will produce more creative students with enhanced chances to perform better in KCSE and with enhanced ability to solve day to day chemistry problems.

ii. The teacher training colleges should design curriculum favouring integration and use of DTA during development of instructional materials to enhance innovative pedagogies and teaching approaches which eliminates mental and cultural blocks.

iii. Teachers in secondary schools should be encouraged to use other inquiry based teaching approaches to enhance acquisition of Scientific Creativity levels among secondary school science students.

6.4 Suggestions for Further Research

Based on the findings of the study, the following areas have been identified for further research:

i. Studies involving other subjects and other classes should be carried out to determine the effect other teaching approaches on Scientific Creativity. Such a study could give an insight into the benefits of such approaches for students at different levels of learning.

ii. Studies should also be carried out to determine the effect of Discovery Teaching Approach on Scientific Creativity by gender.

iii. Studies should be carried out to determine the willingness and preparedness of chemistry teachers to use DTA in day to day teaching of chemistry.

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APPENDICES

Appendix A: Training Manual For Teachers

Introduction

An approach is a wider set of principles, beliefs or ideas about the nature of learning which is translated into the classroom during instruction. Generally, there are two teaching approaches namely: teacher centered and learner centered. Teacher centered approaches involve direct instruction by the teacher who is the expert to a passive learner. Student centered approaches involve a cooperation between the teacher and the learner, where the learner is at the center of the learning process and the teacher acts as the facilitator. Student centered approaches are inquiry based, that is encouraging exploration and discovery and involves an active and cooperative learner.

Discovery Teaching Approach

This is a teaching approach that is associated with methods that are inquiry based, which enables learners to discover facts and relationships, new truths to be learned by themselves, with varying extents of guidance by the teacher who is the facilitator of the learning process. Discovery approach is based on constructivist theory of learning which was put forward by Dewey, (1938), with similar claims by Bruner (2009) and Piaget (1973). Bruner (1961) asserts that practice in discovering by oneself teaches one to acquire information in a way that makes information more readily viable in problem solving. Constructivist teaching fosters critical thinking and creates active and motivated learners. Fosnot (2013) recommends that a constructivist approach be used to create learners who are autonomous, inquisitive thinkers who question, investigate, and reason. Discovery teaching approach can therefore be used to enhance scientific creativity amongst learners during chemistry instruction.

Scientific creativity

Refers to the ability to find new problems and the ability to formulate hypotheses, which involves some addition to our prior knowledge. Scientific creativity abilities include sensitivity to scientific problems, recognition of relationships and flexibility in reasoning.

Sensitivity

This is the ability to be aware of the problem and thinking of possible solutions to the identified problem. This ability makes the student to note and criticize the errors on given problems when wrong calculations, formulae, procedures and solutions are given. James and Bruce, (2001) notes that a creative learner should be able to identify the problem, cite and concentrate on defining the problem appropriately. When wrong or fallacious calculations are given, the student should be able to rectify and do the right calculations. Sensitivity can be taught by exposing learners to erroneous formulae, calculations, solutions and wrong procedures, and give them an opportunity to criticize them so as to come up with the correct ones.

Recognition of relationships

This implies that a creative person should be in a position to recognize relationships, patterns, similarities and connectivity among the concepts and retrieving of the earlier experiences whenever he encounters a novel situation. Students who are able to make connections and cluster related information into categories and relationships can solve new problems with ease (Gobet, 2005). This is applied in chemistry when, for

instance, a student is required to determine the relative atomic mass of an element present in the formula of a compound taking part in a chemical reaction during a titration experiment provided the reacting moles are given. The inter-relationship between formulae for determining the mole, mass, Avogadro's constant and molarity should be emphasized. The teacher should encourage the learner to relate various formulae and methods and units in solving new problems.

Flexibility in reasoning

This is when a learner is able to generate a variety of ideas when solving a problem even when it is not necessary to do so. Flexible learners provide more than one solution to a given problem. Jeffrey, (2005) points out that creative ideas are generated when one discards preconceived assumptions and attempts new methods that may seem otherwise unthinkable to others. This is enhanced by encouraging the learners to provide a variety of solutions to any problem presented. Rather than sticking to only one way or method of solving the problem, let them pursue different ways of arriving to the solution, whether same or different

How to teach by discovery

Discovery teaching approach involves engaging students to exploration, guided by the teacher and materials in the acquisition of the content.

The most outstanding aspect of discovery is enhancing learner participation by encouraging questioning, discussion, experimentation and exploration of ideas and concepts through the guidance of the teacher. The teacher is the facilitator who helps the learners to link the previous knowledge with the current subject matter. He also guides the discovery so that the learners remain focused and avoid wasting time on unnecessary discoveries. The teacher does not dominate the learner, but both cooperate to generate new knowledge. When a failure occurs in discovery, it encourages the learner to continue searching for more solutions (Chia, 2004). Here, the teacher encourages and guides on other avenues to discover without letting the learner despair.

Mole concept

According to Dahsah and Coll (2008), there are few topics which chemistry students find more difficult to understand than the concept of the Mole, yet for its mastery it is absolutely essential to use chemical reasoning. Other studies have shown that students' understanding of the mole concept presents a number of challenges to learners. For instance, Staves & Lumpe (1995) as cited in Barchok (2011) investigated secondary school students' understanding of the mole and their application of the same in solving problems. They found that some students identified the mole with a number of particles while others identified it with mass in grams; even though the mole concept had been defined according to the International System. They also found that students had insufficient understanding of the concepts and had rote use of algorithms and rules.

Introduction to the concept of the mole

The mole is one of the seven units in the Systeme Internationale (SI), officially defined as the amount of substance which contains as many elementary particles as there are carbon atoms in 0.012 kg of carbon-12. The elementary entity must be specified and may be an atom, a molecule, an ion, an electron or a specified group of such particles (Dahsah & Coll, 2008). If the mole concept is introduced properly, this

will enable the learner to understand the mole concept and be able to apply it in solving problems.

The simplest way of introducing the mole is through "counting and weighing". This approach would portray the mole as a "counting unit" which is important in chemistry where we deal with small and many particles which are difficult to count physically. Such include atoms, molecules, electrons, and ions. This approach is going to use counting units which the learner is conversant with such as pair, dozen, ream, decade, century, etc. The teacher will avail various items and place them in different counting units such as ream of papers, pair of shoes, Dozen of books, century of years and assign each of them some fixed number. For example;

Unit / item	Number	Number of items
Pair of shoes	1	2
Ream of papers	1	500
Mole of elementary particles	1	602,300,000,000,000,000,000,000 (6.023×10^{23})

All the items in each of the counting units above, except the mole can be physically counted. The mole can thus be defined as the amount of the substance which contains as many particulate entities or elementary particles as there are in 0.012kg (12g) of carbon-12. Or an amount of any substance that contains 6.023x1023 number of particles. This number of particles is constant for every mole of a substance and it is called the **Avogadro's number.** This can further be buttressed by weighing and comparing masses of various items in different number of units of counting:

a) Pair

Number of units	Item	Number of items	Mass (g)
1	Shoes	2	400
1	Spectacles	2	150

b) Dozen

Number of units	Item	Number of items	Mass (g)
1	Eggs	12	500
1	Mangoes	12	2000

c) Mole

Number of units	Item	Number of particles	Mass (g)
1	Sodium		
1	Magnesium		

It can be concluded from this date that pairs or dozens of different items have same number of items but different masses. So does a mole of any substance have same number of particles but different masses for different elements or substances.
This knowledge can be used to determine various relationships that are necessary to do the calculations such as:

a) Changing mass of a substance to moles

Prior knowledge- how to determine mass of a substance in the laboratory by weighing them on a balance. Learners also need to recall that we can find the molar mass of an element from the periodic table. How then do we obtain the number of moles of a substance once we have known its mass in grams? This is done by dividing the given mass by molar mass. That is;

Number of moles = $\frac{\text{mass of substance sample}}{\text{Molar mass of substance}}$

Example:

You are provided with a sample of magnesium whose mass is 2.4 g. How many moles of magnesium do you have?

Solution

Prior knowledge: molar mass of magnesium from periodic table is 24g/mol.

Number of moles = $\frac{2.4}{24}$ = 0.1 mol

NB: provide further problems in this category to provide some ground to discover further ways of calculating.

b) Changing number of moles to mass

If we know the molar mass, then we can convert any given number of moles to mass.

Example:

i) What mass of calcium is contained in 0.25 moles of calcium?

Ask the learners to apply the formula developed in section (a) above to discover how this calculation can be done.

Solution

If number of moles = $\frac{\text{mass}}{\text{Molar mass}}$; then making mass the subject of the formula;

Mass = number of moles x molar mass;

Hence ; 0.25 x 40 = 10g.

c) Changing number of moles to particles and vice versa

One mole of a substance contains 6.023×10^{23} particles (which must be specified)

e.g I mole of oxygen gas contains 6.023×10^{23} of molecules and 1.246×10^{24} atoms of oxygen

Example;

I) How many molecules of nitrogen are contained in 0.5 moles of nitrogen gas.

II) Determine the number of oxygen atoms contained in 0.1 moles ozone gas(O_3)

d) changing mass to number of particles and vice versa

The molar mass of a substance contains 6.023×10^{23} of particles

Example:

I) calculate the number of molecules of ammonia(NH_3) present in 1.7g of ammonia gas

II) How many lead ions and nitrate ions are there in).% moles lead(II)nitrate

e) Application

Here the learner will be expected to apply the principles so far obtained in the previous sections and solve further problems that require establishment of the relationships between the phenomena. This will demand careful understanding of the questions and logical interpretation of the relationships.

Example ;

i) Determine the number of molecules present in 64g of oxygen

ii) Determine the number of atoms present in 64g of oxygen.

NB: notice that question (i) asks for molecules while (ii) asks for atoms. It should be realized that ne molecule of oxygen contains 2 atoms.

f) Relative molecular mass/ relative formula mass

What is the relationship between relative atomic mass and relative molecular/formula mass?

Example:

i) Determine the relative molecular mass of a compound whose formula is $C_4H_8O_2$

ii) Determine the relative formula mass of a compound whose formula is $MgCO_3$

NB: RMM is for molecular compounds while RFM is for ionic compounds.

g) Empirical and molecular formula

Empirical formula is the simplest formula, which expresses the composition by mass of a compound and expresses the ratio of the numbers of the different atoms in a molecule. Molecular formula on the other hand expresses the actual number and kind of atoms present in the molecule.

Molecular formula and empirical formula are related in that the molecular formula of a compound is a factor of the empirical formula.

Example:

i. If a compound is made up of 2.07g of lead and 0.32g of oxygen, what is its empirical formula? (Pb=207,O=16)

	Pb	O
Mass in grams	2.07	0.32
Number of moles	$\frac{2.07}{207}$	$\frac{0.32}{16}$
	=0.01	=0.02
Find ratio by dividing by the	$\frac{0.01}{0.01}$	$\frac{0.02}{0.02}$
Smallest number	=1	=2
Number of atoms	1	2
Thus Empirical formula =	PbO_2	

ii. An organic compound contains 26.7% carbon, 2.2% hydrogen and the rest is oxygen. If its relative molecular mass is 90, determine its molecular formula. (C=12, H=1, O=16).

h) Mass-mole-volume problems

These are based stoichiometric equations and the mass-Relative atomic mass relationships established earlier on. Emphasis should be placed on proper understanding and interpretation of the problem, the logical approach, and the steps followed.

Example:

I. If 9g of iron powder reacts with chlorine gas at Standard Temperature and Pressure (STP), to produce Iron(III) chloride, determine:
   a) The volume of chlorine gas that reacted
   b) Mass of Iron(III) chloride formed (Fe=56,Cl=35.5)

Solution

Write a balanced chemical equation and use it to determine the reacting mole ratios.

$2Fe+3Cl_2 \longrightarrow 2FeCl_3$: 2 moles of iron react with 3 moles of chlorine to form # moles of iron(III) chloride.

a) Moles of iron = $\frac{9g}{}$

56g/mol = 0.161 moles

But from the equation 2 moles of iron reacts with 3 moles of chlorine hence number of moles of chloride to react with 0.161 moles of iron is given by $0.161 \times \frac{3}{2}$ =0.2415 moles

Since 1 mole of chlorine occupies 22.4 dm^3 at STP,

0.2415 Mole occupy; $\frac{22.4\ dm^3 \times 0.2415}{1}$ =5.41 dm^3

Objective of activity: Help learners find out molar gas volume at RTP and STP and use in calculations.

b) From the equation, number of moles of iron is equal to moles of iron(III) chloride (2:2)

Hence moles of $FeCl_3$ =0,161. Molar mass of $FeCl_3$ is 162.5

Thus mass of 0.161 mole = 0.161 x 162.5 = 26.2 g

NB: provide other problems to provide room for application of the concept and further discoveries in doing the calculations.

i) Volume-volume problems

Example:

I) In a reaction to prepare ammonia gas, 15dm3 of hydrogen gas were reacted with 10 dm3 of nitrogen gas. Determine:

a) The volume of the gas that was not completely used in the reaction.

b) The volume of ammonia gas produced in the reaction.

Solution:

a) Write the balanced equation and use it to determine the reacting volume ratios.

$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$

1 vol 3vol 2vol

From the equation thus; 3dm^3 of H_2 reacts with 1dm^3 of N_2 hence 15dm^3= $\frac{1 \times 15}{3}$ = 5dm^3 of N_2 will react meaning N_2 was in excess and that 5dm^3 of N_2 remains unreacted. (10-5 = 5dm^3

b) 3 vol of H2 produce 2 vol of ammonia. So 15 vol will produce:

$\frac{2 \times 15}{3}$ =10 vol. of NH_3 or 10dm^3 of NH_3

NB: provide other problems dealing with combination of gases leading product/unreacted reactant mixtures to further on application of the concept.

j) Calculation of reacting quantities

This is based on the correct stoichiometric equations and reacting mole ratios.

Example:

I) Copper (II) oxide is reduced by heating with excess hydrogen to form copper metal. What mass of copper(II) oxide will react with hydrogen to produce 8g of copper?

Solution

Balanced equation: $CuO_{(s)} + H_{2(g)}$ $Cu=H_2O_{(g)}$

From the equation, underline what is known and what is to be calculated. Then find the mole ratio for the same.

1 mole of copper(II) oxide produces 1 mole of copper metal

But 1 mole of CuO has RFM of 63.5+16=79.5

Thus 79.5 CuO produces 63.5g of copper:

How much produces 8g of copper?

$\frac{79.5 \times 8}{}$

63.5 =10.02g

How else would this problem be solved?

II) A customer needs 110 tonnes of zinc. How many tonnes of ZnO would you require to be reduced by carbon to produce that amount of zinc?

k) Molar solutions and volumetric analysis

Appendix B: Discovery Teaching Approach Implementation Schedule

The following lesson plan was used during the whole process of instruction using discovery teaching approach.

Implementation Schedule of five weeks for Form Three chemistry

Part A: Topic: The Mole: Formulae and Chemical Equations

Second Term, week 1-5

1. a) Define the mole.
   b) Relate the mole to relative atomic mass.
   c) Convert mass into moles and vice versa.
2. Determine empirical and molecular formulae of compounds from experimental results and given data.
3. a) Explain terms concentration, molarity, and dilution of a solution.
   b) Define molar solution.
   c) Prepare molar solution.
4. Carry out titrations and do calculations involving molar solutions
   a) Acid-base titration
   b) Back titration
   c) Redox titration
5. Molar gas volume and atomicity of gases

a) Definition
b) State Avogadro's and Gay-Lussac's law
c) Carry out calculations related to Avogadro's and Gay-Lussac's laws.

Part B: Content

1. a) Mole as basic unit-molar mass.
   b) Relative atomic mass and mole as number of particles

c) Conversion of mass in grams to moles and vice versa.

2. Quantitative determination of composition of magnesium oxide and copper (ii) oxide.
3. a) Preparation of molar sooultions
   b) Molarity of a solution

c) Concentration and dilution of a solution
d) Stoichiometric equations

4. Titration

a) Acid-base titration
b) Use of ionic and full formulae equations in calculation of reacting quantities
c) Redox titration using potassium manganite (VII)/Iron (II) ions and potassium dichromate (VI)/ Iron (II) ions.

5. Molar Gas volume

a) Molar gas volume and atomicity of gases
b) Avogadro's and Gay-Lussac's laws and related calculations.

Part C: Objectives (week 1-5)

The teacher will facilitate performance of activities to help learners to:

1. a) Define the mole and Avogadro's constant
   b) Convert mass into moles and moles into mass
2. a) Define and calculate empirical formulae from experimental and theoretical data.
   b) Calculate the molecular formulae from given experimental and theoretical data
3. a) Define concentration, molarity, molar solution, and dilution of a solution

b) Prepare molar solutions

4. a) Identify and set up apparatus for titration.
   b) Carry out acid-base, back and redox titration.

5. a) Define molar gas volume and atomicity of gases
b) State Avogadro's and Gay-Lussac's laws and perform related calculations.

Part D: Requirements: Equipment/Apparatus/Materials

Nails, books, weighing balance, pencils, Bunsen burner, match box, crucibles, retort stands, test tubes, boiling tubes, conical flasks, white tiles, sodium chloride, sodium hydroxide, sodium hydrogen carbonate, stock hydrochloric acid, stock sulphuric (VI) acid, potassium manganite (VII), ammonium ferrus sulphate.

Part E: Activities (week 1-5)

1a) carry out 'counting by weighing experiment'
b) Use charts and black/white board illustrations to show relative atomic masses of elements.
c) Use black/white board illustrations to calculate moles/mass
2. a) Heating magnesium in air to determine empirical formula
b) Use theoretical data to calculate empirical formula on the board.
3. a) Use orange juice in different containers to explain concentration/dilution.
b) Experiment to prepare molar solutions
c) Use black board, textbooks and ICT facilities to calculate concentration/ molarity of solutions
4. a) Carry out titration experiments
b) Use titration experimental data to carry out related calculations.
5. a) Use text books or black/white board illustrations to carry out calculations based on Avogadro's and Gay-Lussac's laws.

Part F: Assessment

Revise work for week 1-5 and test the learners to establish whether they understood what was taught.

1. a) How many chlorine atoms are there in 1 mole of chlorine molecules?
b) What mass in grams will contain 1 mole of hydrogen molecules?
c) Calculate the number of molecules in 5 moles of nitrogen gas
d) Calculate mass of 0.5 moles of calcium (Ca=40)
e) How many moles are there in 2.3 grams of sodium (Na=23)
2. a) A hydrocarbon was found to contain 55% carbon, 9% hydrogen and 36% oxygen.
(i) What is its empirical formula?
(ii) If its relative molecular mass is 88, what is its molecular formula?
3 a) When 34.8 grams of potassium sulphate were dissolved in 500cm^3 of distilled water, calculate:
(i) The concentration of potassium sulphate in grams per litre
(ii) The molarity of the solution (K=39, S=32, O=16)
b) Determine the molarity of a solution containing 1.06g of sodium carbonate dissolved in:
(i) 250cm^3 of distilled water
(ii) 500cm^3 of distilled water
c) Explain how a 500cm3 solution of 1.0 M potassium hydroxide solution can be prepared (K=39, O=16, H=1)
d) Calculate the volume of 11.8M hydrochloric acid that will be required to prepare 3.1 litres of 1.8M hydrochloric acid solution.
e) Calculate the volume of water that is to be added to 20cm^3 of 12.4M hydrochloric acid solution to make 2M solution.
4.a) If 25cm^3 of a 0.1 M sodium carbonate solution neutralized a solution containing 2.5g of Sulphuric (VI) acid in 250cm^3 of solution.

(i) Calculate the mmolarity of sulphuric (VI) acid
(ii) Volume of the acid used
(iii) Write equation from the reaction from this information.

5. a) If 0.32g of oxygen occupy $224cm^3$ at standard temperature and pressure, calculate its relative formula mass.

b) Under influence of a catalyst, ammonia reacts with oxygen according to the following equation.

$4NH_{3(g)}+5O_2 \quad 4NO_{(g)}+5H_2O_{(g)}$

Given that $200cm^3$ of ammonia were reacted with excess oxygen, calculate the volume of nitrogen (II) oxide and steam produced.

Appendix C: Chemistry Creativity Test (Cct)

Sensitivity to problems

a) The following problems have been erroneously solved. Correct the errors and do the right calculations.

1. Calculate the concentration of of a 12.5 cm^3 solution containing 0.5g of anhyndrous copper(ii) sulphate in $Moldm^{-3}$. (C=64,S=32,O=16) (2 marks)

Solution:

$12.5cm^3 \longrightarrow$ 0.5g

$1000cm^3 \longrightarrow$ x

$$x = 1000cm3 \times \frac{0.5}{12.5} = 40g$$

$$\frac{40g}{100cm3} = 0.04mol/dm3$$

2. Y g of anhyndrous potassium carbonate were dissolved in water to a final volume of 500cm3.25cm^3 of this solution required 20cm^3 0f 0.2M Nitric acid solution for complete neutralization.Calculate the value of y.(K=39,C=12,0=16,N=14,H=1) (2marks)

Solution: Potassium carbonate reacts with the acid as follows:

$K_2CO_3 + HNO_3 \longrightarrow KNO_3 + CO_2 + H_2O$

0.2 mol are contained in 1000cm^3

X mol are contained in 20cm^3

$$x = 0.2mol \times \frac{20cm3}{1000cm3} = 0.004mol$$

Reacting mole ratio; carbonate: acid = 1:1. Therefore moles of carbonate= 0.004

0.004 mol K_2CO_3 contained in 25cm^3 of solution

X mol contained in 500cm^3

$x = 0.004 \times \frac{500}{25} = 0.08\ of\ CaCO_3$

RFM of K2CO3 =126

If 126 $\longrightarrow$ 1 mol

Y $\longleftarrow$ 0.08 mol

Y = 126x0.08 = 10.08g

3. Calcium Oxide is made by heating Calcium Carbonate in the following reaction:

$CaCO_3 \longrightarrow CaO + CO_2$

Calculate the quantity of limestone, containing 90% $CaCO_3$ that is required to make 160 tonnes of CaO (2 marks)

1 mole of CaCO3 produces 1 mole of CaO

RFM of CaCO3 = 120 and that of CaO = 56

Thus 120 g CaCo3 produces 56 g CaO:

Similarly, 120 tonnes CaCO3 produces 56 tonnes CaO

x tonnes CaCO3 produces 160 tonnes CaO

$$x = 120 \times \frac{160}{56} = 342.86\ tonnes$$

But limestone is 90% pure,thus: $342.86 \times \frac{120}{90} = 433.09\ tonnes$

4. The questions below present experimental procedures that have errors leading to erroneous solutions and conclusions. Identify the errors and hence determine the correct solutions to the problems.

a) In a titration experiment, Njoki was provided with the following:

- 3.15g oxalic acid($H_2C_2O_4.2H_2O$)solid

- 100 cm^3 NaOH solution B
- Phenolphthalein indicator

She was required to determine the molarity of NaOH solution using the procedure given below.

- ✓ Transfer all the solid A into 250cm^3 conical flask. Add 100cm^3 of distilled water and shake to dissolve the solid.
- ✓ Add more water to make up to 250cm^3 0f solution and label this solution A.
- ✓ Fill a burette with the prepared oxalic acid solution A.
- ✓ Pippete 25 cm^3 of solution B into a clean conical flask.
- ✓ Run the acid into the flask.
- ✓ Record the new burette reading and determne volume of the acid used.
- ✓ Repeat the procedure two more times and calculate the average of the three titres.

(i) However, after carefully following the above procedure, Njoki was unable to obtain any volume of the acid used(titre). Analyze the procedure and explain to her why she could not obtain any titre and make the corrections that would make the experiment work (4 marks)

Recognition of Relationships

The following problems require application of chemistry concepts to everyday problems or relating certain general observations to some scientific concepts learnt in the topic of the mole concept.

1. A compound of carbon, hydrogen and oxygen contains 54.55% carbon, 9.09% hydrogen and 36.36% Oxygen. If its relative molecular mass is 88, determine the molecular formula of the compound. (C=12,O=1 (2 marks)
2. Determine the molarity of a solution containing 1.06g of sodium carbonate dissolved in 500cm^3. (Na=23, C=12, O=16) (2 marks)
3. What volume of 0.12M Sulphuric (VI) acid exactly neutralizes 100cm^3 of 0.1M sodium hydroxide (2 marks)
4. In a redox titration, a solution of Ammonium Iron(II) sulphate $(NH4)_2SO_4FeSO_4.nH_2O$) salt was prepared by dissolving 8.5g of its crystals in 50cm^3 of sulphuric (IV) acid and the volume made up to 250cm^3 of solution. 25cm^3 of this solution completely reacted with 22.0 cm^3 of 0.02 M potassium manganite (VII) solution to the endpoint.
   a) Calculate the number of moles of potassium manganate (VII) [KMnO4] that reacted. (1 mark)
   b) Given that the ionic equation for the reaction is as shown below, determine the number of moles of the Iron(II) salt in 25cm^3 of the solution used. (1mark)

      $MnO_4^- + 8H^+ + 5Fe^{2+} \quad Mn^{2+} + 5Fe^{3+} + 4H_2O$

   c) Determine the molarity of the Iron (II) salt solution and hence value of n in the formula $(NH4)_2SO_4.nH_2O$ (2 marks)

Flexibility in reasoning

These are the problems that require the students to reason out so as to give many possible solutions to the same problem or specially designed experimental procedures that give room for various ways of solving a particular problem.

1. Johanna was provided with the following reagents and apparatus by her chemistry teacher: clamp stand, burette, filter funnel,25cm^3 pipette, conical flask, white tile and dropper,0.5M Hydrochloric acid solution, phenolphthalein, indicator and sodium hydroxide solution of unknown

concentration. She was required to experimentally determine the concentration of the sodium hydroxide solution by titrating it with the hydrochloric acid. However, she later reported to the teacher that she was unable to do it. Her teacher referred her to you to help her solve the problem. Elaborately describe to her three different ways by how she could carry out the experiment to determine the required concentration. (6 marks)

2. Calculate the volume of carbon (IV) oxide gas measured at standard temperature and pressure (STP) which is evolved when 4.2 g of magnesium carbonate is heated is heated to constant mass. Show different ways by which the same problem could be solved (4marks)

Appendix D: Chemistry Creativity Test Marking Scheme

Sensitivity to problems

A)

1. $12.cm^3 \longrightarrow 0.5g$

$1000cm^3 \longrightarrow ?$

$\frac{1000 \times 0.5}{12.5} = 40g/e$

$M = \frac{\text{mass per litre}}{RMM}$

$= 40/160 = 0.25M.rt2131$

2. $K_2CO_{3(s)} + 2\,HNO_{3(aq)} \quad 2KNO_{3(aq)} + CO_{2(s)} + H_2O_{(aq)}$

Moles of $HNO_{3(aq)}$

$= \frac{0.2 \times 20}{1000} = 0.004$

$K_2CO_3 : HNO_3$

$1 \quad 2$

Moles of K_2CO_3 that reacted

$= 0.004 = 0.002$

2

$0.002 \longrightarrow 25cm^3$

$? \longleftarrow 500$

$\frac{0.002 \times 500}{25} = 0.04moles$

$Moles = \frac{\text{mass on grams}}{\text{molecular mass}}$

$0.04 = \frac{y}{138}$

$y = 0.04 \times 138 = 5.52g$

3 $CaCO_{3(s)} \quad CaO_{(s)} + CO_{2\,(g)}$

Moles of $CaO_{(s)} = \frac{160 \times 10_6}{56} = 2857142.8571$ moles

Moles of $CaCO_{3(s)} : CaO_{(s)}$

$1 : 1$

Mass of $CaCO_{3(s)} = 100 \times 2857142.8571$

$= 2.857 \times 10^8$

But the limestone is 90% pure $CaCU_{3(s)}$

thus;

$\frac{2.857 \times 10^8}{90} = \frac{100 \times 10^6}{}$ = 317.4603 tonnes

4.a)(i) Correct Procedure

Transfer all solid A.

ii)Correct data and table:

Titration	I	II	III
Final burette reading	24.5	49.0	27.5
Initial burette reading	0.0	24.5	27.5
Volume of acid used(cm^3)	24.5	24.5	27.5

Errors noted:

- Values for final and initial readings inverted
- Use of decimal points not consistent
- Volume values not consistet within the acceptable ± 0.2
- Principal of averaging not based on the consistent values

Recognition of relationships

1.

	C	H	O
% mass	54.55	9.09	36.36
RAM	12	1	16
Moles	$\frac{4.546}{2.275}$	$\frac{9.09}{2.275}$	$\frac{2.275}{2.275}$
	2	4	1

EF = C_2H_4O

MF = $(C_2H_4O)n = 88$

$(24 + 4 + 16)n = 88$

$(44)n = 88$

$n = \frac{88}{44}$ $n = 2$

MF = $(C2\ H4\ O)_2$

$= C_4H_8O_2$

2.Na_2CO_3 = 106

Moles = $\frac{1.06}{106}$

= 0.01 moles

0.01 $500cm^3$

0.02 ? $1000cm^3$

$\frac{0.01 \times 1000}{500} = 0.02M$

3. $H_2SO_{4(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2SO_{(aq)} + 2H_2O_{(I)}$

Moles of NaOH = $\frac{0.1 \times 100}{1000}$

= 0.01 moles

H_2SO_4 : NaOH

1 : 2

Moles of H_2SO_4 that reacted with NAOH

$\frac{0.01}{2}$ = 0.005 moles

Vol of H_2SO_4 ; 0.12M $\longrightarrow$ $100cm^3$

0.005 $\longrightarrow$?

$\frac{0.005 \times 1000}{0.12} = 41.6667cm^3$

4. a). Moles of $KMnO_4$ = $\frac{0.02 \times 22}{1000}$ = 0.00044

b). $MnO4^-_{(aq)} + 8H^+ + 5Fe^{2+}{}_{(aq)}\ Mn^{2+}{}_{(aq)} + 5Fe^{3+}{}_{(aq)} + 4H_2O_{(I)}$

Mole ratio MnO^{4-} : Fe^{2+}

1 : 5

Moles of Iron (II) salt = $\frac{0.00044 \times 5}{1}$

= 0.0022 moles

c). 0.0022 $25cm^3$

? $1000cm^3$

$\frac{0.0022 \times 1000}{25}$ = 0.088M

Flexibility in reasoning

1. Procedure
   - Mount burette on the clamp stand and place the set up on the bench.
   - Place a white tile or plain white paper below the burette mounted on the stand.
   - Place a filter funnel on top of the mounted burette and fill the burette with the 0.5M HCl acid solution to exactly $0.0cm^3$
   - Pipette 25cm3 of the NaOH solution and put it in a conical. Into this solution add 3 drops of phenolphthalein indicator. The solution turns pink.
   - Place the conical flask under the mounted burette and on the white tile.
   - Open the burette tap and run the acid solution into sodium hydroxide solution drop by drop as you shake. Continue doing so till the pink solution just turns colourless. This is the endpoint.
   - Read the burette and record the volume of the acid used in a tabular form.
   - Repeat the procedure two more times and get three consisitent results. Tabulate the results as shown below.
   - Use the results to calculate the average volume of the acid (titre)used in the reaction.
   - Use the average titre to calculate the concentration of NaOH hydroxide as shown:
   - Sample results

Titration	I	II	III
Final burette reading	25.0	25.1	24.9
Initial burette reading	0.0	0.0	0.0
Volume of HCl acid used(cm^3)	25.0	25.1	24.9

Average titre = $\frac{25.0+25.1+24.9}{3}$ = $25.0cm^3$

Equation for the reaction: $HCl_{(aq)}+NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$

Reacting mole ratio: 1:1

Moles of HCl in 25cm3 = $\frac{0.5 \times 25}{1000}$ = 0.0125 moles

Thus moles of NaOH in 25 cm3 = 0.0125 moles

Concentration of NaOH in mol/litre = $\frac{0.0125 \times 1000}{25}$ = 0.5M

2. $MgCO_{3(s)} \longrightarrow MgO_{(s)} + CO_{2(g)}$

   moles of $MgCO_3$

   = $\frac{4.2}{84}$

   = 0.05 moles

   Mole ratio of $MgCO_3$: CO_2 is 1 : 1

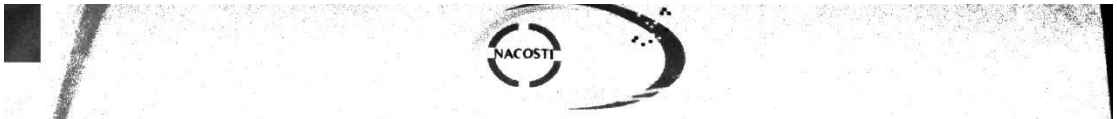
Appendix E: Chemistry Class Observation Schedule

School…….....Class……Age(years)……Date…Time……

The researcher observed learner's psychological behavioral responses reflecting sensitivity, recognition and flexibility as aspects of scientific creativity in the chemistry classroom. The teacher normally taught as the researcher checklisted any behavioral reactions or responses (based on the arrays) from the learners as the teacher taught.

Students' Responses/Reactions									
Time intervals within the lesson (minutes)		5	10	15	20	25	30	35	40
Sensitivity Arrays (Sa)									
Sa1	Identifies errors or omissions in calculations								
Sa2	Seeks clarity from the teacher/other learners								
Sa3	Intrinsically takes notes during the lesson								
Sa4	Offers alternatives to methods, and formulae.								
Sa5	Positively critiques and redefines ideas								
	Recognition Arrays (Ra)								
Ra1	Recalls facts, ideas, formulae and topics studied earlier								
Ra2	Identifies patterns, relationships and similarities								
Ra3	Associates earlier experiences with the current								
Ra4	Responds by Citing related ideas from other topics								
Ra5	Generalizes patterns, variations and formulae								
	Flexibility Arrays (Fa)								
Fa1	Tries to modify other learners' ideas, building on them								
Fa2	Suggests alternatives to solve problems in class								
Fa3	Making attempts despite several failures								
Fa4	Consults other learners or teachers when stuck								
Fa5	Explains to others what he/she is doing to on B/board								

Appendix F: NACOSTI Research Permit



NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

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Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/18/18884/23989**

Date: **24th July, 2018**

Edward Karithi Kirianki Ikiao
Chuka University,
P. O. Box 109-60400
CHUKA.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Effect of discovery teaching approach on scientific creativity amongst students of chemistry in Public Secondary Schools in Imenti North Sub-County, Kenya"*** I am pleased to inform you that you have been authorized to undertake research in **Meru County** for the period ending **24th July, 2019.**

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

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Meru County.

The County Director of Education
Meru County.

Appendix G: Ministry of Education Research Authorization

REPUBLIC OF KENYA
MINISTRY OF EDUCATION
State Department of Early Learning and Basic Education

Telegrams: " ELIMU " Meru
EMAIL: cdemerucounty@gmail.com
When Replying please quote

County Director Of Education
Meru County
P.O. Box 61
MERU

Ref: MRU/C/TDU/11/1/202

16th August, 2018

TO WHOM IT MAY CONCERN

RE: RESEARCH AUTHORIZATION – EDWARD KARITHI KIRIANKI IKIAO

Reference is made to letters Ref: NACOSTI/P/18/18884/23989 dated 24th July, 2018.

Authority is hereby granted to **Edward Karithi Kirianki Ikiao** to carry out research on **"Effect of discovery teaching approach on scientific creativity amongst students of chemistry in public secondary schools in Imenti North Sub County, Kenya"** in Meru county" for a period ending **24th July, 2019.**

Kindly accord him the necessary assistance.

for COUNTY DIRECTOR OF EDUCATION
MERU COUNTY
P. O. Box 61 60200
TEL: 064 30372 MERU

Dr. Sawega Walala (PhD)
For: County Director of Education
MERU

Appendix H: Ministry of Interior Meru County Research Authorization Letter

THE PRESIDENCY
MINISTRY OF INTERIOR AND COORDINATION OF NATIONAL GOVERNMENT

Telegrams:
Telephone:
Email: ccmeru@yahoo.com
Fax:

COUNTY COMMISSIONER
MERU COUNTY
P.O. BOX 703-60200
MERU.

When replying please quote
Ref: *ED.12/5 VOL III/253*

Date: 16th August 2018

TO WHOM IT MAY CONCERN

RE: RESEARCH AUTHORIZATION

EDWARD KARITHI KIRIANKI IKIAO

This is to inform you that **Edward Karithi Kirianki Ikiao** of **Chuka University** has reported to this office as directed by Commission for Science, Technology and Innovation and will be carrying out Research on "**Effect of discovery teaching approach on scientific creativity amongst students of chemistry in Public Secondary Schools in Imenti North Sub County, Kenya.**"

Since authority has been granted by the said Commission, and the above named student has reported to this office, he can embark on his research project for the period ending **24th July, 2019.**

Kindly accord him any necessary assistance he may require.

W. K. Katonon
For: County Commissioner
MERU