EFFECTS OF SEQUENTIAL TEACHING METHODS ON ACHIEVEMENT, RETENTION AND TRANSFER OF KNOWLEDGE IN BIOLOGY BY SECONDARY SCHOOL STUDENTS IN KENYA

BY

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been presented for a degree in any other university. No part of this research thesis may be reproduced without prior permission of the author and/or Pwani University.

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DEDICATION

To my family.
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I would like to thank all individuals who contributed and sacrificed their time towards the writing and completion of this thesis. To my supervisors, Prof. Helen Mondoh and Dr. Chrilukovian Bwire Wasike for their guidance and support in the development of this research thesis; their advice and criticism made this thesis what it is.

I also thank all the Biology teachers and students in the schools where the research was conducted. Additionally, I give my gratitude to Mr. Stephen Amukune and Mr. Ezekiel Some who helped in data analysis as well as Ms. Jane Rukwaro and Winnie Namasaka for typing and editing the manuscript. Sincere thanks to my family and colleagues for their support and encouragement.
Despite the importance of knowledge in Biology, candidates’ performance at the national examination; The Kenya Certificate of Secondary Education (KCSE) is poor. This could be attributed to the teaching methods. The purpose of this study was to compare differential effectiveness of Sequential Teaching Methods (STM) on the achievement, retention and transfer of knowledge in Biology by secondary school students. The study was Quasi-experimental using the Non-equivalent control-group 16 study design. There were four groups divided into eight (8) sub-groups: four Boys only schools and four Girls only schools to allow for investigation of gender. All the four groups took a pre-test, post-test, knowledge retention test and a transfer of knowledge test to make a total of 16 observations. The target population comprised students in the 18 old category National Schools in Kenya that were in existence before 2012. Purposive sampling was used to obtain a sample of eight (8) schools and 402 Students. The students in the eight (8) sub-groups were taught the same Biology topic: “General Characteristics of Enzymes”, using different sequences of three teaching methods namely: lecture, slide demonstration and laboratory (student experiment). Group I (ELD) began with experiments, followed by lecture method and was lastly shown, animated slides. The sequence of the three different methods used in the first group was altered in both the second and third groups as follows: The lecture method, slide demonstration and laboratory experiment (LDE) for Group II, and slide demonstration, experiment and lecture method (DEL) for group III. Students in group IV (control group) were taught using (oral-only) lecture method. The teachers gave lectures and performed slide demonstration while the students carried out laboratory experiments. In order to quantitatively measure achievement based on the various sequences of teaching the researcher used the Biology Achievement Test (BAT). The test was used as a pre-test and also post-test. In addition, it was also used as a retention test that was administered 40 days after the Post-test BAT. This test had 25 objective questions testing knowledge of facts, application of knowledge and problem solving ability. To measure Transfer of Knowledge, the researcher used Concept Maps as an assessment tool. The four research hypotheses were tested using ANOVA at significant level of 0.05. The results and findings of the study show that STM, when efficiently used in instruction, could enhance immediate post achievement test scores, retention and transfer of knowledge in Biology more effectively than the oratory lecture method predominantly used in Kenyan Secondary schools. Furthermore, DEL sequence was identified as the most effective in comparison to LDE and ELD. The findings of the study will help curriculum developers and teachers to choose the most appropriate sequence to use in Biology.
ABBREVIATIONS AND ACRONYMS

ANOVA - Analysis of Variance
BAT - Biology Achievement Test
BKRT - Biology Knowledge Retention Test
CEMASTEIA - Center for Mathematics and Science Teacher Education in Africa
DEL - Demonstration method – Experiment method – Lecture method
ELD - Experiment Method – Lecture Method – Demonstration Method
KCPE - Kenya Certificate of Primary Education
KCSE - Kenya Certificate of Secondary Education
KIE - Kenya Institute of Education
KNEC - Kenya National Examination Council
LDE - Lecture method – Demonstration Method – Experiment method
MDGs - Millenium Development Goals
MoEST - Ministry of Education Science and Technology
NCST - National Council of Science and Technology
SMASSE - Strengthening of Mathematics and Science in Secondary Education
STM - Sequential Teaching Methods
STMA - Sequential Teaching Methods Approach
TT - Transfer Test
UNESCO - United Nations Environmental Scientific and Cultural Organization
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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Biology education has both intrinsic and extrinsic justifications (Brown, 1995). The former relates to advancement in Biology for its own sake as a discipline while the latter is concerned with the promotion of societal welfare. Inferably, the teaching and learning in Biology play both academic and social roles. Killermann (1998), explains that the academic role concerns the acquisition of scientific knowledge, skills and attitudes for application in the fields of medicine and agriculture among others. The social role pertains to the empowerment of individuals in economic and technology related areas.

The overall goal of teaching Biology in Kenya is to make learners to fully understand themselves and the environment (Maundu, Sambili & Muthwii, 1998). In addition, it enables students to appreciate mankind as part of the broader community of living things. Biology is also a precursor of Biotechnology, which is a vital tool for technological and industrial development. The teaching in Biology therefore, aims at the production of a scientific community whose major role is to promote the welfare of humankind through application of knowledge in Biology. In addition, Biology fosters the advancement of science through research and publications (Lawson, 2001).

Since independence, efforts have been made to improve standards of teaching Biology in Kenya through educational reforms. Maundu, Sambili & Muthwii, (1998) report that, the African Curriculum Development Centre (ACDC) established in 1963; later KIE (1974-2013) and now KICD (2013), made the first attempt at improving the teaching in Biology. The center produced Biology schemes of work and lesson plans for use by secondary schools teachers. The argument then was that teachers in Biology were not qualified to
prepare schemes of work and lesson plans on their own. However, according to Maundu, Sambili & Muthwii (1998), the ACDC project failed due to [1] teachers’ incompetence [2] lack of teaching resources in schools. The United Nations Educational, Scientific and Cultural Organisation (UNESCO) launched the UNESCO pilot project as the second intervention in 1967. The project aimed at improving teaching of Biology, and laid emphasis on investigation, observation and discovery rather than rote learning and memorisation of facts. In addition, teaching was based on students interests and experience. The project led to the production of students’ laboratory manuals and teachers’ guides. Maundu, Sambili and Muthwii (1998) pointed out that the UNESCO pilot project made wrong assumptions concerning the availability of ordinary standard equipment in the pilot schools. Upon the project launch it became apparent that most schools lacked the standard laboratory equipment. This became one of the constrains that led to the project failure.

Another effort to improve teaching in Biology was the Nuffield Science Project launched in 1969. This succeeded the UNESCO pilot project. The project was introduced through the Technical Assistance Programme whereby books, apparatus and equipment were shipped to Kenya from England. Only a few schools were selected to participate. This project was found to be ambitious and required sophisticated apparatus and too much of the students time, hence its abandonment in 1972.

Thereafter, the School Science Project (SSP) was launched in 1974 as an indigenous programme involving the then East African States (Kenya, Uganda and Tanzania). However, the SSP Biology was modelled on the Nuffield Science Project but excluded the sophisticated apparatus. The SSP project focused on answering of questions based on students’ experiments. Students were therefore expected to keep a detailed laboratory notebook record. At the launch of this project only 15 schools were selected. However, the number increased to 25 and by 1982, the number had risen to slightly over 50 schools, that were spread in
various parts of Kenya. Like the previous projects the SSP faced a number of challenges that necessitated it to be offered alongside the traditional Biology Syllabus.

The traditional Biology syllabus was based on the conventional methods in which the teaching is expository. Although students perform experiments they merely serve to verify known information. The syllabus persisted for many years because it did not require too much equipment and materials. Traditional Biology was later modified to suit the current 8-4-4 Biology Syllabus that commenced in the mid-1980s.

Since its introduction in 1986, the 8-4-4 Biology syllabus has undergone four reviews: 1992, 1997, 2002, 2006. The aim of these reviews was to align, scale-down and re-arrange the content taught at various levels. The review of 2006 was accompanied by a change in the examination format whose details are outside the scope of the current study.

In an attempt to achieve objectives of the Secondary School Biology syllabus, KIE (2006) suggested several methods of teaching. The methods include: practical work, class discussions, demonstrations, excursion/field trips and project work. However, the baseline survey done by the project, ‘Strengthening of Mathematics and Science in Secondary Education’ (SMASSE, 2007), shows that the predominantly used teaching methods for Biology include: lecture method, teacher demonstration and practical/laboratory work (student experiment). The Biology syllabus in Kenya is organised in such a way that for most theory lessons, mainly taught through the lecture method, there is corresponding practical work. The recommendation by KIE (2006) is that practical or laboratory work should be done through either teacher demonstration or student experiments; allowance is made for practical lessons to be done before or after theory lessons. This in effect constitutes Sequential Teaching Methods Approach (STMA). However, in actual fact, Biology teachers in Kenya often use only lecture method (without demonstrations and experiments) in their
lessons (Njuguna, 1998). Any attempt of STMA in teaching Biology in Kenya mainly follows the sequence: lecture method, teacher demonstration and student experiments (LDE). It is however, important that these methods be used in an appropriate sequence (pattern). In an effort to help the teachers implement the Biology syllabus effectively, emphasis is laid on the teachers’ use of a combination of methods for a single topic (KIE, 2006). However, this may not be practically possible due to constraints such as lack of material resources and even space that curtail use of variety of teaching methods.

Biology teachers usually resort to use of lecture method owing to the aforementioned constraints. Consequently, learners miss the hands-on experiences, which enhance learning. The result is rote memorisation of information as opposed to meaningful learning. Mondoh (2005) observes that, in most lessons the whole difference lies in the fact that the student is asked to accept from outside an already organised intellectual discipline which he/she may or may not understand.

Biology provides a foundation for careers in the related fields and is a precursor for technological advancement. In Kenya, it is also one of the stepping stones to industrial transformation and Kenya’s Vision 2030. Biology is part of our daily lives, and good Biology education could help give learners a great foundation for success in life. It could also help learners develop into more responsible citizens who will help to build a strong economy, contribute to a healthier environment and bring about a brighter future in the society.

Teaching method has been singled out as an important factor that determines learning outcomes (Trumper, 2006). It fosters or hinders learning. The teaching method used therefore affects achievement, retention and transfer of knowledge.
In Kenya, the secondary school Biology curriculum provides for the use of Sequential Teaching Methods. High achievement, retention and transfer of knowledge in Biology provides concrete evidence of meaningful learning. This is consistent with the goal in Biology Education which is to promote the welfare of humankind through application of knowledge in Biology. The knowledge can be applied only if it is retained and transferred to different contexts of life. Transfer occurs when a concept learned at one time and place is applied to another setting. This application goes on in every day life. Transfer is investigated in this study because it is dependent on the student’s ability to access, connect and retrieve information retained in the long term memory. The retention of knowledge in turn depends on its meaningfulness.

Research conducted by Wachanga & Mwangi, (2004) in Kenya to find out effects of various teaching methods on achievement in science subjects shows that cooperative class experiment as a teaching method enhances learners’ achievement and motivation in Chemistry and Agriculture respectively. The findings of another study by Kibett and Kathuri (2005) involving secondary school students in Nakuru County, showed that learners who were taught Agriculture using the project method performed better than their counterparts who were taught using the regular approach, mainly by lecture. In a related study, Orora, Wachanga and Keraro (2005) found that the cooperative Concept Mapping teaching method enhanced achievement and motivation in secondary school Biology in Gucha County, Kenya. Other studies (Johnson, 1991; Odubunmi & Balogun, 1991; Killermann, 1998; Esra, Ijlal and Ocak, 2009) have been carried out to determine the effectiveness of different methods of teaching Biology. The findings of these studies show that the methods of laboratory and slide demonstration are very effective in teaching Biology.

Research done by Esra, Ijlal and Ocak (2009), conducted in Turkey at Arturk University sought to determine the effect of Sequential Teaching Methods in Biology, on students’
achievement and retention. The study aimed at determining the effects of Sequential Teaching Methods under three teaching modes; lecture, slide demonstration and laboratory (student experiment) on academic achievement, retention and transfer of knowledge in Biology by learners.

However, all the aforementioned studies involved a single teaching method except the study by Esra, Ijilal and Ocak (2009) who used a combination of methods. Their study is in line with KICD’s suggestion on effective methods of teaching Biology; hence the interest of the researcher in this study.

A study such as that by Esra, Ijilal and Ocak (2009) had not been done in Kenya. The current study is a replication of the aforesaid study but with some adjustments. Esra’s study was quasi-experiment that used only three non-equivalent groups. The present study used four groups with eight sub-groups as described in section 3.2. In addition, a control group that was taught using oral-only lecture method was also included. Furthermore, Concept Mapping was included as a tool to measure transfer of knowledge; this was absent in Esra’s study. The present study also included transfer of knowledge in Biology as a third variable in addition to achievement and retention. This study therefore, aimed at finding out the effects of Sequential Teaching Methods (STM) on secondary school students Biology achievement, retention and transfer of knowledge in Kenyan National schools.

According to the reports by the Kenya National Examination Council (KNEC 2007-2012), the KCSE mean scores in Biology for the period 2007 to 2010 were as follows: 2007- 44%; 2008- 30%; 2009- 27%; 2010- 29%; 2011- 32% and 2012-26%). Accordingly, performance was influenced by many factors but the magnitude of each factor was not known. This research sought to put things in perspective instead of speculation.
1.2 Statement of the Problem

Despite the government’s effort to review curriculum as well as change the examination format, students’ performance in the KCSE Biology National examination continues to decline. Low achievement in Biology at KCSE examinations may imply that the information given is not sufficiently retained in future years of study and not consequently transferred for general use in life. Studies by (Wachanga & Mwangi, 2004; Kibet and Kathuri 2005; Orora, Wachanga and Keraro 2005; Esra, Ijlal and Ocak 2009) have been carried out in Kenya and elsewhere to compare effects of teaching methods on academic performance. These studies observed that teaching methodology is a crucial factor in determining academic performance of students. Mills (1991), observes that the teaching methodology is a crucial factor that affects academic achievement of students. Esra, Ijlal and Ocak (2009) suggested that the sequence of teaching methods affected performance. The Kenya 8-4-4 Biology syllabus recommends use of STM; this has six possible combinations of sequences-LDE, LED, ELD, DLE and DEL. Information based on empirical studies on whether the STM was effective, and which sequence had greatest effect on academic performance in Biology in the Kenyan context was lacking. The determination of the best sequence was also important. However, a study on STM based on Kenyan conditions had not been conducted. The study therefore sought to address the problem of determining whether STM was an effective method of teaching Biology, and identifying the best sequence on achievement retention and transfer of knowledge.

1.3 Purpose of the Study

The purpose of the study was to determine which sequence (pattern) of the three Sequential Teaching Methods (lecture, demonstration and experiment) must take precedence in order to increase learners’ academic achievement, knowledge retention (remembrance) and
knowledge transfer to Concept Maps. As such, the study sought to evaluate differential effectiveness of three versions of Sequential Teaching Methods namely; ELD, DEL and LDE.

1.4 Objectives of the Study

The study sought to:

1. Compare the effect of Sequential Teaching Methods on Academic Achievement of learners taught Biology using different sequences.

2. Compare the retention of Knowledge of learners taught Biology using different sequences of Sequential Teaching Methods.

3. Compare the transfer of knowledge to Concept Map among learners taught Biology using different sequences of Sequential Teaching Methods.

4. To establish which sequence among the sequential teaching methods had greatest effect on achievement retention and transfer of knowledge in Biology

1.5 Hypotheses of the Study

The following null hypotheses were tested:

Ho1 There is no difference in learners achievement in Biology when they are exposed to different sequences of teaching methods.

Ho2 There is no difference in retention of knowledge in Biology when learners are exposed to different sequences of teaching methods.

Ho3 There is no difference in transfer of knowledge in Biology when learners are taught using different sequences of teaching methods.
Ho4 There is no difference in effect of sequence used on learners’ achievement, retention and transfer of knowledge in Biology

1.6 Significance of the Study

Kenya’s Biology syllabus suggests use of STM in all the four broad areas of Biology:- Anatomy, Physiology Morphology and Histology. The findings of this study should inform Curriculum developers and teachers in choosing the most appropriate teaching sequence for Biology. In addition, the findings should also inform teachers to arrange lessons such that sequences that yield highest achievement are followed. Policy makers and Quality Assurance personnel could use the findings to enforce policy on Sequential Teaching Methods. Furthermore, literature on transfer of knowledge in Biology is very scanty. The findings of this study, besides contributing to existing knowledge should contribute immensely to literature.

1.7 Scope and Limitations of the Study

1.7.1 Scope of the Study

The study involved eight National schools selected across the country, out of the 18 Old Category National schools established in the pre and post colonial era, and upgraded to national status between 1960s and 1980s. The scientific scope of the study was confined to the secondary school Biology curriculum implementation. Focus was on the effectiveness of methodology. The main idea was to find out the most appropriate sequence of teaching methods that could help learners to improve in achievement, retention and transfer of knowledge in Biology.
1.7.2. Limitations of the Study

The schools that were involved in the study were those endowed with resources that could support STMA. As such the results obtained are only generalisable to schools of similar status. Only three sequences out of the six possible options of STM were used since the current study was a replication of Esra, Ijilal and Ocak (2009) study that focused on ELD, LDE and DEL. The study was also limited to the area of Physiology and excluded other broad areas of Biology namely:- Anatomy, Morphology and Histology.

1.8 Assumptions of the Study

The study was based on the following assumptions:-

The non-scientific assumptions were:

(1) That the main cause of poor academic results (failure) was the quality of instruction as opposed to students inability to learn.

(2) That since National schools were subjected to a common admission criterion, all the four groups and eight (8) sub-groups of students from the eight different schools were of similar learning ability.

(3) That the gender of the teacher did not affect achievement.

While the Scientific assumptions were:

(4) Each sample was drawn from a normal population.

(5) Each population had same variance

(6) All variables other than those tested were effectively controlled hence absence of other factors that could affect the conclusion.
1.9 Theoretical and Conceptual Framework

The theoretical framework provided the foundation on which the study was based, while the conceptual framework presented an elaborate network of associations among the relevant variables of the study.

1.9.1 Theoretical Framework

The study was guided by two theories: [1] the General Systems Theory proposed by Bertalanft (1968). Noting that a system is an interrelationship of various elements which work in unison to achieve a designated goal, each element or variable in the system has its own specific roles to perform. In addition to the elements and goals, a system also has to work in harmony so as to give the expected feedback at the end of the process. This is applicable in the teaching-learning situation. Based on the General Systems Theory, the teaching in Biology involves elements that include the teacher, learners, teaching-learning process, teaching-learning resources and physical facilities such as the classroom. The current study involves independent, dependent and extraneous variables. All these variables must interact with each other in order to move the system from an input condition of original or entry behaviour to an output condition of modified behaviour. The expected modified behaviour, for instance higher achievement, retention and transfer of knowledge serve as the goal of the system whereas actual achievement serve as feedback of the teaching process. The desired goals have to be achieved however, feedback could be positive or negative performance. The quality of feedback is therefore determined by the quality of interaction among the elements or variables hence the need for harmony. The General Systems Theory guided the conceptual framework.

[2] The Cognitive Load Theory of learning proposed by Sweller (1994). According to this theory the working memory is finite and has limited capacity. The information received
through the auditory channel gets direct access to the working memory thus clogging it. This affects information processing.

The treatment given to the learners in the study was based on this theory, the human working memory has a threshold of 4 to 10 elements making some material difficult to learn. Sweller (1994), provided evidence that the cognitive load of some learning material can be greatly reduced if the information is presented pictorially or otherwise as in the case of lecture and slide demonstration.

1.9.2 Conceptual Framework

Several factors or variables interact and affect learning. The variables could be categorised as extraneous, independent and dependent. These variables and their interactions constitute the conceptual model of this study. The conceptual framework that guided this study is based on the General Systems Theory. Accordingly, the teaching and learning process has inputs and outputs. Therefore, in order to achieve good academic results, the input should have appropriate instructional methods. Damico and Roth (1994) noted that quality education is defined in terms of output such as the number of students passing an important national examination. Thus a school of students with low achievement scores is said to be of low quality or non-performing. However, Fowler (1995) observed that “a diagnosis of school quality problem that focuses on outputs such as student performance fails to inform about the antecedent causes such as teaching methods.

Arguably, learning outcomes are influenced by several factors. In the study, these included both learner and teacher characteristics which, and constituted extraneous variables that had to be controlled. As explication, the learners’ age determines what they are to be taught. Teacher’s qualifications and training on the other hand determine the instructional approach that a teacher would prefer to use more often and how effective the teacher would use the
approach. Gender of learners was an extraneous variable which could not be controlled but whose effect could also not be ignored.

The conceptual framework shows the relationship of variables for determining the effects of using sequential teaching methods on secondary school students’ achievement, retention and transfer in Biology knowledge. The framework is represented diagrammatically in Figure 1.

Figure 1: The Conceptual Framework

1.10 Operational Definition of Terms

Achievement in Biology means the score (marks) that learners obtained on Biology Achievement Test (BAT) Post-Test (refer to Appendix II).

Concept Map: Is a graphical representation of the relationship between various concepts as contained in the mental structure of the learner. For purposes of this study, Concept Map means the research instrument that was used as an assessment tool. It was used to assess transfer of knowledge originally learned via Sequential Teaching Methods to the new context of Concept Mapping (see Appendix IV).
Laboratory work, also referred to as students’ experiment, is the method whereby the teacher provided learners with resource materials so that they could manipulate to observe enzyme activity. Learners performed experiments to examine catalytic features of enzymes, factors and relation between substrate and enzymes.

Lecture Method means an oral presentation that was given to a class by the teacher and did not involve manipulative work. This was used to teach the relevant theory of enzyme action.

National Schools refer to those government funded schools that admit students with highest scores at Kenya Certificate of Primary Education (KCPE) examination. The schools are equipped with adequate and standard physical facilities for teaching, learning and boarding. Selection of students to such schools is done on merit by the Form One Selection Committee of the Ministry of Education Science and Technology (MoEST). They accommodate students from all districts of the Republic of Kenya. The School performance index at the Kenya Certificate of Secondary Education (KCSE) examination must always be greater than six on a scale whose maximum is twelve.

Old category of National Schools refer to the oldest, historic and prestigious schools that were established in the pre and post colonial era and were given national status between 1960s and 1980s. Some of these schools were owned by independent churches but not adequately funded yet, demand for them was high. The teachers were well trained, qualified, competent and held in high esteem. They were eighteen in number and all are endowed with adequate teaching and learning resources (refer to Appendix VII). They admitted good performers in the KCPE examinations, from all the districts of the Republic of Kenya. They have a small teacher: student ratio and are usually headed by a Chief Principal or Senior Principal. Their class size ranges from 35 to 45 students.
**New category National schools** refer to those which were upgraded from provincial status to national status in 2012. This category comprises of 72 schools.

**Retention** in Biology means the score obtained on the Biology Knowledge Retention Test (BKRT) see Appendix III.

**Sequential Teaching Methods** refers to an umbrella term that embodies a specific pattern of different methods that were used one after another in teaching the specified topic. In this study, sequential teaching methods meant the following three patterns:

- Experiment → Lecture → Demonstration (ELD)
- Lecture → Demonstration → Experiment (LDE)
- Demonstration → Experiment → Lecture (DEL)

**Figure 2: Patterns of Sequential Teaching Methods (STM)**

**Slide demonstration** method is where the teacher showed slides and explained to the class about the structure and function of enzymes using a prepared Power-Point teaching tool in Microsoft Office software or via overhead projection.

**Transfer** in this study means the score obtained on the Concept Map constructed by each learner (see Appendix IV).

**Transfer Test:** Means the assessment of learner’s knowledge that involved drawing of Concept Maps using the concepts that had been learned through the Sequential Teaching Methods (STM).

**Transfer of Knowledge:** Means utilising the concepts previously learned via Sequential Teaching Methods to a new context namely Concept Mapping. Whereby, Concept Maps were constructed by the learners.
CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews literature on methods of teaching Biology, focusing on pedagogical parameters based on selected theories of teaching and learning. It also analyses literature on Sequential Teaching Methods in relation to achievement, retention and transfer of knowledge. It finally presents findings of previous empirical studies on Concept Mapping in Biology and ends with a brief summary.

2.1 Teaching Methods and Achievement

Educationists all over the world are struggling to develop effective teaching and learning approaches (Borich, 2004). According to Blisset and Atkins (1993), decisions should be made when choosing teaching strategies that are appropriate to the learning styles. In order to enhance teaching and learning, teachers in Biology are encouraged to use a variety of methods and strategies (KIE, 2006). In addition, these methods and strategies should be used effectively so as to optimise the attainment of instructional objectives (Kithaka, 2003). However, a study by the SMASSE Biology team in Kenya, aimed at identifying the needs in Biology Education at Secondary school revealed that teaching was largely expository, using the lecture method (Njuguna, 1998). It was therefore a worthwhile effort to extend the search for more effective combinations of teaching methods for Biology through this current study. The researcher sought to know, understand and prescribe Biology teaching methods that would be effective so as to inform the pedagogical practices in secondary schools.

The teaching methods commonly used in secondary schools in Kenya are: lecture method, Teacher demonstration and laboratory work (student experiments). Despite limited
documentation, the effect of teacher demonstration on achievement, retention and transfer of knowledge are discussed in the subsequent sections.

2.1.1 Effect of Lecture Method on Learners’ Achievement

The traditional lecture method is an oral presentation given to a group of learners by the teacher. Odubunmi & Balogun (1991) described it as a method of teaching outside of manipulative work. Killermann (1998) and Havice (1999) found it unsuitable for teaching Biology. However, this method is most effective for transmission of large amounts of subject content. Teachers are usually comfortable with the traditional lecture method because they remain in control of both content and time. It enables the teacher to present information in a logical and coherent order in a short time (Brown, 1995). The researcher perceives lecture method as translation of the subject matter to learners by telling, so that they can synthesise their own meanings. It could be the best type of teaching if only it could lead to increased acquisition and use of knowledge.

According to Aziz (1990), achievement requires encoding, which is an active process of putting information into memory. It is a matter of forming cognitive representation of information. Evidence from various disciplines indicate that oral presentation to a large group of passive students contributes very little to meaningful learning. Brown (1995), attributes the criticism against the lecture method to its failure to offer learners training for the attainment of scientific skills.

Furthermore, lecture method is boring especially if lengthy and if the teacher lacks appropriate communication skills. The content taught is thus quickly forgotten. Inspite of the criticism, this method is still commonly used in Kenya as a result of large class sizes; a consequence of Free Primary Education. The introduction of free primary education in Kenya in 2003 has seen a significant increase in enrollment whose graduates require placement in
secondary schools. For instance in National schools where the demand for Form One vacancies is very high, large class sizes have become a reality. Enrollment in some schools ranges between 50 and 60 students per class. Large class size could affect the teaching of science which, should be practical and visual in nature.

In physics, for example Horn (1995) observed that standard oral-lecture method seldom helps learners to develop conceptual understanding of fundamental processes in mechanics and electricity. Similarly, learner’s performance in Chemistry taught only by lecture method does not correlate with the lecturing skills and experience of the teacher. Despite the limitations of traditional oral – lecture method, Biology teachers are forced to use it due to high enrolment rates (Committee on Undergraduate Science Education, 1997). Most teachers who teach large classes feel that lecturing is the only option. The researcher contends that this method should not be considered outmoded. It is still a very useful instructional method and has a specific role in the instructional process. This study sought to shed light on the paradox of teaching Biology. For example, Havice (1999) observed that a lecture is vital for introducing a lesson, explaining relationships between concepts, giving instructions during practical work as well as summarising the results of laboratory work. He further argued that it was an economic way of transmitting information to a large number of students because it did not require a lot of facilities.

2.1.2 Effect of Lecture Method on Learners’ Retention of Knowledge

The concept of retention of formally acquired knowledge is just about three decades old and thus very few empirical studies have been done on it. Bahrick (1984), made the first attempt and found a positive correlation with the depth of original learning. His study therefore provided the basis upon which other studies could be carried out.
The explanation of relative effectiveness of lecture method with regard to retention of knowledge could be sought in learning theories which are conceptual frameworks that describe how information is absorbed, processed and retained during learning. For example, educational neuroscience which supports Multiple Intelligence Theory shows that learning results from interaction between different functional areas in the brain. Each of these areas have their own strengths and weaknesses in any particular human learner (Anderson, Yamagishi & Karavia, 2002). This is the reinforcement of the constructivism theory that humans generate knowledge and meaning through sequential development of an individual’s cognitive abilities as suggested by George (1999).

The cognitivists learning process is adoptive learning of methods to develop internal cognitive structure that strengthen synapses in the brain. Constructivism is concerned about why students do not learn deeply by listening as is the case when using lecture method. According to the multiple intelligences theory, linguistics learners use words effectively. These learners have highly developed auditory skills and often think in words. Gordon & Jeanette (2001) observed that such learners are best taught using the lecture method. However, there is great need for a Biology teacher to find and develop ways to engage learners in the vital processes of thinking, questioning and problem solving despite the use of lecture method. In this way, the oral only lecture method becomes pedagogically sound. However, review of literature avails limited information pertaining lecture method and transfer of knowledge. This study is therefore important as an effort to provide that literature.

2.1.3 Effect of Teacher Demonstration Method on Learners’ Achievement

Demonstration emphasises the important points of a product, a process or an idea. The method combines telling, showing and doing by the teacher as the learners observe and listen. A slide demonstration therefore is a method that involves the teacher showing and explaining
something to the class. This can be done by using power-point teaching tool in Microsoft Office software or classically by using overhead projector. The purpose of a demonstration is to provide a means by which the teacher can explain or clarify certain parts of the content quickly and economically. According to Philip and Roxanne (2004), teacher demonstrations can be used to explain experimental set before the students begin to set up their own apparatus for individual or group activities. It can also be used for verification of observed phenomena or trend of data.

Slide demonstration is one of the ways of assisting learners overcome misconceptions (Katz, 1991). It can thus be a very effective method for illustrating abstract concepts or mechanisms due to its metaphysical and epistemological benefits. Learners’ interest is heightened if they are asked to either predict or suggest a probable outcome. It can provoke learners to think by themselves. However, it can result in passive learning if the teacher does not carefully engage the attention of the learners (Committee on Undergraduate Science Education, 1997). Secondary school Biology teachers in Kenya most commonly use teacher demonstration method due to lack of adequate teaching-learning resources resulting from increased enrolment. According to Johnson (1991), teacher demonstration can be used when the materials are too dangerous or the equipment is too delicate to be entrusted to the learners.

Mayer and Moreno (2002) contends that teacher demonstration as a teaching method is most effective if the teacher involve learners appropriately. Ormrod (2012), on the other hand observes that the educational system as currently constituted, in most countries is heavily biased towards linguistic modes of instruction and assessment. He further argues that the students learn in ways that are identifiably distinctive. Consequently, visual – spatial learners think in terms of space and can best be taught through graphics, drawings and 3-D modeling. Slide demonstration method, preferably with animations would therefore be the most
appropriate teaching method. This view is equally supported by the multiple intelligence theory of learning and the Philosophical or Meutic theory of teaching.

2.1.4 Effect of Teacher Demonstration Method on Retention of Knowledge

The effectiveness of slide demonstration method on retention of knowledge could be attributed to the incorporation of visual media which help students to acquire concrete concepts. According to Pavio (1990), object identification, spatial relationship or motor skills are easily acquired and retained more where words alone (oral-only lecture) are insufficient. Consequently, visual media which portray motion are best to show psychomotor or cognitive domain expectations involving a Biological process such as enzyme action. The major advantage of slide demonstration method is that the media used represent knowledge in a transparent manner that could enable learners to visualise more easily (Keller, 1987). Although research has had limited success in identifying the teaching methods most suitable for both short-term and long-term retention of knowledge. It is on that basis that effects of sequential teaching methods became the focus of this current study.

2.1.5 Effect of Laboratory Method (Experiment) on Learners Achievement

Laboratory work is the hallmark in Biology education. Laboratory work is an integral part of most Biology topics. Student laboratories are an expensive facility yet their educational potential is seldom fully realised in the practice of teaching (Holsten & Lunetta, 1992). It is high time Biology teachers critically examined the usefulness and contribution of learning laboratories to meaningful learning. The priority area of study in this regard is the effectiveness of laboratory activities for promoting high quality learning.

Laboratory method offers learners a more conducive learning environment than the “traditional” classroom setting (Fisher, Hernderson & Hofstein, 1998). This involves
teaching/learning activities conducted by the student under the guidance or supervision of the teacher (Bennet & Higgins, 1996). The teacher provides the students with the materials and apparatus as well as the instructions to be followed in performing the activities. Students work either singly or in groups. According to Hohn (1995), two basic skills are required in order for students to carry out practical work safely and successfully. They include ability to make accurate observations and correct use of equipment and apparatus. He further suggested that meaningful practical work requires the following: preparation before the practical lesson commence, rehearsal with materials to ensure they will yield expected results, clarity of instructions by employing simple and clear language. Other requirements include effective guidance and supervision by the teacher and cautioning learners on any precautionary measures to ensure safety.

Finally, the teacher is expected to establish a link between the practical exercise and the theoretical concepts in focus. A study by Opara (2011), showed that laboratory method has a significant effect on learners’ achievement in Biology. In addition, the study also revealed that learners who are taught using laboratory teaching method in well equipped schools had higher rates of achievement in Biology compared to those schooling in less equipped schools. This finding agrees with that of Njogu (2004) that schools record low achievement due to lack of science laboratories. However, even when laboratories are available in schools, teachers still find challenges in using them due to inadequacy of equipment, which limits practical work (Holstein & Lunetta, 1982; Johnson, 1991; Fisher, Harrison, Hernderson and Hofstein, 1998). Nonetheless the challenges of lack of learning resources could be overcome by improvisation, and should not be used as an excuse.
2.1.6 Effect of Laboratory Method on Learners’ Retention of Knowledge

It is difficult to imagine learning Biology without doing laboratory or fieldwork. Student experimentation underlies all scientific knowledge and understanding (Fisher, Harrison, Hernderson & Hofstaein; 1998). This method provides learners with opportunities to think about, exchange ideas and solve real life problems. Thus, this provides enough evidence that knowledge was retained. Designing a laboratory experiment requires much skill, creativity and hard work. Learners acquire such scientific attitude when teachers use this method. In fact no Biology can be properly taught without use of student experiments. This method should therefore be the central part in Biology teaching since it helps learners to find relationships among concepts and to verify hypotheses.

However, the Kenya secondary school Biology syllabus emphasises use of a variety of teaching methods. A combination of several methods for a particular topic is thus recommended hence need for sequential teaching methods. As in other disciplines, the effectiveness of a Biology lesson is dependent on the teaching method used. A combination of teaching methods may be used together for offering a topic. It is on that premise that the current study was carried out. Findings of previous research on effects of sequential teaching methods on achievement and retention in Biology are discussed in the subsequent subsections.

2.1.7 Effect of STM on Achievement and Retention in Biology

Previous research by Semb and Ellis (1994), Esra, Ijlal and Ocak (2009) defined a number of variables which affect achievement and retention of knowledge as described in subsequent text. According to Semb and Ellis (1994), these include the amount of original learning and the instructional strategies used. Results of a study done by Esra, Ijlal and Ocak (2009) in
Turkey showed that academic achievement for the groups that began with experiment or slide demonstration was higher than group beginning with lecture method. The effectiveness of laboratory (student) experiment or slide demonstration at the commencement of the lesson supports the idea that the lesson attracts the attention and thus increases the motivation of the learners. On the other hand, using oral-only lecture increases boredom in learners and makes them lose attention during the lesson. This sentiment agrees with the findings of Odubunmi and Balogun (1991) and Gentry (1994). A possible explanation for the scenario is that a visual material supplies comprehension that words alone cannot express and thus makes learners to remember the contents of learning easily. The learners also have more time and opportunities for hands-on-experience and development of teamwork spirit.

The findings of the study by Esra, Ijlal and Ocak (2009) revealed that retention (remembrance) level for groups that began lessons with experiment or slide demonstration was higher than that of the group which began with lecture. This result also agrees with the findings of previous researches (Chandler & Sweller, 1991; Bransford, Brown & Cocking, 1999) which show that; people remember 10% of what they read, 20% of what they hear, 30% of what they see and 90% of what they have hands-on experience. Likewise, the study conducted by Esra, Ijlal and Ocak (2009) also revealed that learners’ comprehension is enhanced when lessons begin with experiment since practical activities increase learners interest in the topic. These results could be adapted to any other teaching cases elsewhere in the world.

2.1.8 Effects of STM on Learners’ Transfer of Knowledge in Biology

Transfer of knowledge means the influence of prior learning (retained until the present) upon the learning of, or response to new material (Mc George, 1942). Transfer, therefore, has enormous practical implications for education in schools. Despite its importance, it is
disappointing that the progress made towards understanding of knowledge transfer is not commensurate with the amount of research that has been done on the phenomenon for a good recent review (Barwett & Ceci, 2002). One factor that hinders progress in this aspect of transfer of knowledge is the traditional approach to the study. Studies on transfer of knowledge (Barwett & Ceci, 2002), focus mainly on the similarities and differences between the contexts of initial learning and subsequent transfer. This was an indication for need of not only further studies in the area, but also a more non-traditional approach to studies.

Furthermore, a related previous study by Esra, Ijilal and Ocak (2009), focused on university students, and on achievement and retention based on recall and recognition of knowledge. The study did not consider the structure of knowledge, depth of understanding and conceptual relationships. This suggested need to conduct a similar study but focusing on a lower tier of education and consideration of other aspects of learning, hence adaptation of the earlier related study. Esra, Ijilal and Ocak (2009) did not investigate transfer of knowledge, hence the need to use Concept Maps in addressing the issue of transfer of knowledge.

2.1.9 Effect of Concept Mapping on Learners’ Transfer of Knowledge

As a result of too much emphasis on the transfer context as a limiting factor, relatively few studies take the alternative approach of exploring how the conditions of initial learning can be arranged to better promote transfer to many different possible contexts. If initial learning produces better retention of information and numerous retrieval routes to access that information, it should increase the possibility of a match between the cues given in the transfer task and the store memory trace. Studies on Concept Mapping indicate that it is one of the suitable strategies that can be used to break away from traditional approach of studying transfer of knowledge as it provides many retrieval routes. Transfer of knowledge is based
on the finding that Concept Mapping is an appropriate knowledge evaluation tool (Rice, Ryan & Samson, 1998).

Concept Maps have been used successfully to promote meaningful learning and effective teaching and are helpful in representing qualitative aspects of students’ learning (Derbentseva, Safayeni & Canas, 2006). The whole idea of Concept Mapping is based on the assertion that human beings are meaning makers and thus the human brain endeavors to construct order from apparent chaos (Edwards & Fraser, 1983).

Canas and Novak (2006), described a Concept Map as a visual, structured representation of concepts and their interrelationships. They further described Concept Mapping as the process that involves identification of concepts contained in study materials and the organization of those concepts into hierarchical arrangements from the most general, most inclusive to the least general, most specific. Edmonson (2000), noted that the key concepts in a Concept Map are linked with lines bearing propositions (logical connectives).

Briggs, Shamma, Canas, Carf, Scarge and Novak (2004) proposed that the concepts be represented using colour coding and various shapes of concept boxes for different concept types. Concept Maps provide teachers with an avenue for developing insight into students’ understanding. The researcher contends that this is evidenced by well-organised and richly elaborated knowledge structures, valid propositional relationships and interrelationships. The Concept Maps also help to identify errors, omissions or misconceptions.

Briggs et al. (2004) showed that simple Concept Maps consists of two or three concepts linked by propositions. Cana and Novak. (2005), further proposed the following pedagogical aspects could benefit from application of Concept Mapping: advanced organising of learners’ thoughts at the start of a subject topic, planning and consequent delivery of the lesson,
summarising contents of the topic so as to help learners revise and lastly, assessment of students achievement.

Semra, Caren and Omer (2001) acknowledge that the way the course content in Biology subject taught in schools is presented, gives the impression that each topic consists of a series of separate chunks of information. This impression clutters the content or the subject matter. Students fail to make clear links between related or associated concepts. The researcher alludes to the idea that among the many concerns teachers in Biology are left to grapple with are the following: First, the best way to convey the many concepts that are taught in Biology so that all learners can retain and use the information. Second, presentation in Biology content so that concepts are interconnected to build upon each other. And lastly, making Biology content to be meaningful and relevant to the learners.

Laver and Wenger (1990) formulated the Situated Learning Theory in which they urged that learning as it naturally occurs is a function of activity, context and culture in which it takes place. Supported by the contextual learning theory, learning occurs only when learners process new information using their own frame of reference, experiences, and responses in a way that makes sense to them. Accordingly, teachers should prepare learning experiences that relate subject matter content to real-world situations. They should aim to motivate learners to make connections between knowledge and its applications to the learners’ lives. Biology should therefore be taught and learned in the context of daily life, technology, community, or society. Concepts could be easily internalised through the use of Concept Mapping technique.

The researcher asserts that the burden then rests on the teachers to highlight links in the development of their work, so students can appreciate, Biology as an interconnected body of knowledge. This approach adopts the belief that true knowledge and understanding can be developed in the learner and by the learner, through the transformation of fragmented,
compartmentalised bits of knowledge into knowledge of personalized meaning (Bransford, Brown & Cocking, 1999). They further suggest that the student is required to make conscious effort to identify the key concepts in new knowledge and relate these key concept to concepts in his/her existing knowledge structure.

It can be deduced from the aforementioned literature that Concept Mapping as a learning strategy requires learners to organise a set of related concepts that make up the content of a lesson. A Concept Map shows the relationships between concepts including bi-directional ones. Usually, a Concept Map is divided into nodes and links. Nodes (often circles or boxes) represent key concepts; links (lines) represent relationships (propositions) between concepts (Vitale and Romance 2000). The link is represented by an arrow, which indicates the direction of the relationships. Words are used to label the links in order to depict more explicitly the relationships. The relationship is written on the line.

Concept Mapping is therefore a highly flexible tool that can be adopted for use by almost any group of learners. Where possible, the concepts are anchored with specific examples. While each concept can only appear in one place on the map, it may be linked to any number of others. Briggs et al (2004) observed changes in students’ maps which showed that cognitive structures are in a continual state of flux in an active learner. A Concept Map therefore has a ‘limited shelf life’, after which it is simply an historical record. The active use of Concept Maps could be applied to any of four stages of the teaching/learning process: Planning and preparation; Formative learning; Revision/summarising; Assessment. They are all discussed in the section that follow with an exception of the first one.

Edmodson (2000) suggested adoption of the following steps in the construction of Concept Maps:

1) Select about 12 concepts from the biology content material being considered.
2) Write each concept on a separate note card. Lay these cards down on a large sheet of paper.

3) Select a super ordinate (most general) concept to be placed at the top of the map.

4) Arrange the other concepts in a distinct hierarchy under the super ordinate concept.

5) Once the concepts have been arranged, draw lines between related concepts and label each linking line with words that characterise the relationship between those concepts.

6) If you wish to cross-link two concepts in different branches of your map, use a dashed line and label their relationship by writing on the linking line.

7) Examples, if they are to be given, should be connected to their source concepts by an e.g. labeled linking line.

It was therefore a worthwhile idea for students to master the skill of Concept Mapping so that they could use it as described in the text that follow.

2.1.9.1 Concept Mapping and Formative Learning

A Study by Namasaka, Mondoh and Keraro (2013) showed that Concept Mapping helps students to gain more unified understanding of a topic and organise their knowledge evidenced by enhanced achievement and motivation in Biology. For ‘holists’, who have a global approach, Concept Mapping helps the learners to focus on critical details, whereas, ‘serialists’ can be stimulated to take a wider perspective of the subject matter. However, Rice, and Samson, (1998) reported that students who gain most from Concept Mapping are those identified as ‘visual-spatial learners’, who excel when provided with visual representations. Such students reject rote memorisation and have need to see how the parts relate to the whole before they can make sense of the isolated ideas typically presented in Biology lessons. This suggests that for teachers to optimise the benefits of Concept Mapping for their students, they first need to be familiar with the students’ prior knowledge and current learning strategies and
styles (Bareholz & Tamir, 1992). This was implicit in the use of the concept map as a tool to measure transfer of knowledge; an indication of meaningful learning.

2.1.9.2 Concept Mapping and Revision

Anderson and Huang (1989) affirmed that Concept Maps are excellent summary/revision tools in which large amounts of information are condensed. The creation of such a map stretches the students’ mind thus deepening and broadening their understanding of the subject matter. Students are enabled to revise actively. Anderson and Huang (1989), further argue that revision by reading through the notes leaves no evidence of the effort that has been made by the learners. With students producing a revision Concept Map to be handed in, the teacher gets much more information about each of his/her students’ performance than would be gained from a test mark alone (Rice & Samson, 1998). Like all teaching and learning tools, Concept Mapping is not a panacea; it will not suit all learners or all learning situations. The researcher therefore, agrees that there are some challenges and/or short comings teachers and learners face while using Concept Mapping. However, concept mapping was not used as a learning tool for treatment in this study.

2.1.9.3 Concept Mapping for Assessment

According to Rice, Ryan and Samson, (1998), once completed, the Concept Map is a visual representation of a learner’s cognitive structure. It shows the hierarchies and the interconnections of concepts learned in a particular lesson. Edmondson (2000), supports the idea that a more practical way of generating a Concept Map is to write each term on a piece of paper. The pieces of paper can be rearranged so that when links are drawn the terms are beautifully laid out. When satisfied with the arrangement, the pieces of paper can be pasted on a big sheet and the relationship linking the terms are written on the lines connecting them.
This means that the map may vary from person to person. More revealing is the nature of the relationships or links between the concepts defined by each person (Preszler, 2004).

As earlier mentioned, there is no wrong or correct map. There is often more than one appropriate link between a pair of concepts; the layout can vary considerably. However there are some criteria and scoring procedures in evaluating Concept Maps.

A number of studies (Leake, Magnitman, Carvalho, & Arguedas 2004) have supported the use of Concept Maps for summative assessment. They also have suggested evaluating student maps by reference to a teacher-produced or ‘expert map’. Student maps could then be marked according to how many of the propositions in his/her are incorporated. This informed the choice of concept map as a tool for assessment in the current study.

2.2 Learners’ Age and Achievement

Age is also an important variable in pedagogy since it determines the school level as well as the content that the learner is taught. According to the National research Council (2014) report, learners age affect teacher-student interactions for example a study of 643 students in 37 secondary school classrooms indicated that the age of the learner is a predictor of teacher-student conflicts, which in turn affect achievement. The researcher found a direct link between the academic achievement of adolescent students and their sensitivity to student needs. The researcher acknowledged the effect of age on achievement and therefore put in place mechanisms for minimising its effect on the findings. Hence its classification as an intervening variable.
2.3 Gender and Achievement

Wasanga (1997) reported that male students normally show more confidence in learning science. However, the same study revealed that female students in single sex schools achieve as well in science subjects. Likewise, research done in 1999 by Forum for African Women Educationists (FAWE), aimed at improving participation and performance of girls in Science and Mathematics in primary and secondary schools indicated that the achievement of Kenyan girls in Science is lower than that of boys. The FAWE (1999) report attributed the gender disparity in performance to teaching methods in which the environment favoured boys as opposed to girls. From literature review, it is evident that students’ gender is an important determinant of achievement. Hence the decision to control its effect in this study.

2.4 Teacher Qualification and Achievement

Allen, Gregory, Mikami, Lun, Hamre and Plianta (2013) confirmed links between teacher qualifications and students learning achievement. Accordingly the more qualified a teacher is the more he or she will be effective in providing opportunities for students to learn.

Similarly, a survey by Ohlson (2009) on the effect of teacher quality on students learning found that achievement of students at schools with highly qualified teachers was higher compared with schools which had lowly qualified teachers. Cohen, Pickeral and McCloskey (2009) noted that there is positive teacher-student interaction and increased learner satisfaction. Additionally, there is focus on learning and high expectations for student learning. Teacher qualifications and in-service training influence the way teachers structure the class rooms and lessons in recognition of the students needs. This suggested need to minimise the effect of this variable on the study findings.
2.5 Teachers in-service Training and Achievement

According to Thapa, Cohen, Guffey and Higgins’ (2013) survey, teachers who had undergone in-service training reported increased tracking of their students’ progress towards measureable academic goals throughout the year, compared to those who had not taken the course. They also made effort to set high standards for their students and develop competence in record keeping on student’s progress. The findings from these researches have important implications for pedagogical approach to achievement. There is need to take a holistic view, factoring in a mix of these predictors in order to maximise students achievement. This study considered inservice training in sampling of teachers.

2.6 Summary

This chapter first covered the Biology teaching methods commonly used in Kenyan secondary schools. It showed that lecture, teacher demonstration and laboratory or class experiment are predominantly used. Project work and field trips are also encouraged by the Kenya Institute of Curriculum Development (KICD) but are rarely used.

Although each one of these methods has own strengths and weaknesses, the theories reviewed supports their importance and role in the teaching in Biology. KICD emphasises use of a combination of teaching methods for a single unit or topic in the subject (KIE, 2006). This however is not always possible due to several constraints that schools face in implementing the Biology syllabus.

The assumption that use of a combination of teaching methods for a single topic may not necessarily translate to or imply use of Sequential Teaching Methods (STM). Utilisation of STM calls for consistent pattern in its application in view of pertinent pedagogical parameters. There is no literature available that highlights use of STM (LDE, ELD, DEL) in
Biology in Kenya. This suggested the need to explore and establish which pattern of the most commonly used methods would yield highest level of academic performance. The primary goal of the present research was to determine which pattern of the Sequential Teaching Method leads to highest achievement, knowledge retention and transfer to Concept Map. A secondary goal was to explore use of Concept Maps as an assessment tool or method for transfer of knowledge in Biology.
CHAPTER THREE
RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents the procedures and the methodology that was used in the study. The chapter is sub-divided as follows: Introduction, research design, location of study, population, sampling procedures, sample size, research instruments, instructional materials, data collection procedures and data analysis.

3.1 Area of Study

The study area covered four regions of Kenya namely: Nairobi, Central, Rift Valley and Nyanza, where Old Category National schools were situated (Refer to Appendices VII & VIII). These regions were selected in order to draw a representative sample from among the 18 old category National schools. These are only found in these regions of the country.

3.2 Research Design

This study was quasi-experimental, using the Non-equivalent Control-Group Sixteen study design. It was found suitable for controlling all the threats to internal validity. All the four groups took a pre-test, post-test, knowledge retention test and transfer test hence a total of 16 observations were made. All the sixteen observations made were used to generate estimations of the effect of the experimental treatment, interactive testing variables and that of the control variables. The general model of the study design is represented in Figure 3.
Figure 3: General Model of the Non-equivalent Control-Group 16 Study Design


Where: O₁, O₅, O₉ and O₁₃ are pre-tests

O₂, O₆, O₁₀ and O₁₄ are post-tests

O₃, O₇, O₁₁ and O₁₅ are retention – tests

O₄, O₈, O₁₂ and O₁₆ are Transfer-tests

X is the treatment where students were taught using sequential teaching methods (STM)

C- means no treatment. It refers to the control group

Group I was the experimental group that received the pre-test, the treatment (X=ELD), the post-test, the retention test and the transfer test.

Group II was the experimental group that received the pre-test, the treatment (X=LDE), the post test, the retention test and the transfer test.

Group III was the experimental group that received the pre-test, the treatment (X=DEL), the post test, the retention test and the transfer test.
Group IV was the control group that received the pre test, followed by the control condition (C=OOL), the post test, the retention test, and lastly the transfer test. Quasi experimental design was used because the classes were naturally formed in the school and remain intact during the study, a view supported by (Creswell, 2011). The classes were randomly assigned to teaching methods (LDE, ELD and DEL) with oral-only lecture method as a control variable. The aim was to evaluate differential effectiveness of STM based on testing of the hypotheses.

The design was suitable for testing and establishing the cause-and-effect relationships between Sequential Teaching Methods and Achievement, Retention and Transfer of Knowledge. According to Sekeran and Bougie (2011), the design allows for manipulation of the independent variable so that the extent of its causal effects could be established. This design is the most comprehensive and also guarantees maximum internal and external validity, ruling out many other rival hypotheses. The study was analytical and predictive in nature; a strategy common in educational research. The research process was thus manipulative not enumerative. It was a snapshot or cross-sectional study where sufficient data was collected at one point in time. Form One classes were used as the unit of analysis. The specific design may be represented as shown in Table 1.
Just as in Esra, Ijlal and Ocak (2009) study, the learners in Group I started the topic with an experiment in the laboratory. This was followed by the relevant theory of enzymes that was taught through the lecture method. Finally the teachers showed the slides on enzyme activity to the learners. The sequence of these three methods of teaching was altered in both group II and III as follows: The lecture method, slide demonstration, experiment for group II and slide demonstration, experiment and lecture method in group III respectively. In all cases the lectures and slide demonstration were performed by the teachers. The lecture method focused on enzyme activity. The students’ experiment was designed for the same reason (Enzyme activity) and including observation of enzyme catalytic features, co-factors, co-enzymes and relationship between enzymes and substrates. The experiment was conducted by the learners under teacher supervision. The slide demonstration method involved use of

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<tr>
<th>Group</th>
<th>Treatment</th>
<th>Effect</th>
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<tr>
<td>Exptl Group I a.(B)</td>
<td>Experiment; Lecture; Demonstration</td>
<td>Achievement</td>
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<tr>
<td>Exptl Group I b.(G)</td>
<td></td>
<td>Retention</td>
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<tr>
<td>Exptl Group II a. (B)</td>
<td>Lecture; Demonstration;Experiment</td>
<td>Transfer</td>
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<td>Exptl Group II b. (G)</td>
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<td>Exptl Group III. a. (B)</td>
<td>Demonstration; Experiment;Lecture</td>
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<td>Exptl Group III b. (G)</td>
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<td>Control group IV.a(B)</td>
<td>Oral-only lecture</td>
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<td>Control group IV. b. (G)</td>
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Exptl- mean experimental
B-mean Boys only School
G-mean Girls only School
slides on the structure and function of enzymes. The slides too were shown by the teachers. The study used graduate teachers who had undertaken the Bachelor of Education Science programme and specifically the Botany/Zoology option. In addition teachers had undergone the Strengthening of Mathematics and Science in Secondary Education (SMASSE) training.

3.3 Variables of Study

The independent variables in this study, were the Sequential Teaching Methods: ELD, LDE and DEL as defined in section 1.10. They were observed and measured using the BAT, BKRT and Concept Map scores as described in section 3.8.

The dependent variables were learners’ achievement, retention and transfer of knowledge in Biology as defined in section 1.10. In this study these variables were observed and measured using scores obtained on BAT, BKRT and Concept Maps as described in Section 3.9.

The extraneous variables in this study were the age and gender of the learners, teacher qualifications and in-service training. These variables were those whose possible effects on the learning outcomes were controlled. The learners’ age determined the subject topic to be covered. Teacher’s qualifications and training on the other hand determined the instructional approach a teacher would prefer to use more often and how effective this would be.

Learners’ age was controlled by using pupils from the same class level; in this case Form One. This is because the topic selected for the study is offered at Form One level. The topic was selected because of replicability considerations, and in addition, the KNEC report (2006), consider enzyme activity to be a difficult topic for learners to conceptualise. Explicitly, the topic consists of many concepts involving complex relations and interactions. Representativeness of gender was ensured by having eight sub-groups where half were boys and the other half were girls. Gender, though an extraneous variable, was investigated since its
effect could not be ignored. Single Sex schools were thus used. Teacher qualification as a variable, was controlled by using teachers who were holders of Bachelor of Education degree (B Ed. Science Botany-Zoology option) and SMASSE trained.

3.4 Population of the Study

All the learners in secondary schools in the Republic of Kenya constituted the population for the study. The schools served as sampling units.

3.4.1 Target Population

According to the Ministry of Education, Science and Technology (2014) statistics, there were approximately 2,514,068 students in 6739 registered secondary schools in Kenya. This was therefore the target student population.

3.4.2 Accessible Population

The accessible population was approximately 86,400 students. It comprised all the classes in Form One to Form Four in the 18 Old category National schools. Although the schools are fairly distributed, some regions of the country had no National schools of the Old Category (Refer to Table 2). The schools were because they were endowed with teaching–learning resources that could support the application of STM.
Table 2: Regional Distribution of Old Category National Schools

<table>
<thead>
<tr>
<th>Region</th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nairobi</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Central Kenya</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Rift Valley</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Nyanza</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Western</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Eastern</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Coast</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>North Eastern</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>9</td>
<td>9</td>
<td>18</td>
</tr>
</tbody>
</table>

3.5 Sampling Techniques and Sample Size

The researcher used the sampling procedure described in section 3.5.1 to obtain the sample size for the study.

3.5.1 Sampling Techniques

The types of National Schools in Kenya were grouped into two main categories:

(i.) Old category National schools established between the 1960s and 1980s. These were 18 in number.

(ii.) New category National schools which were upgraded from provincial status to national status in 2012. This category comprised of 72 schools.

The schools which were included in the sample were obtained from category (i) above. The unit of sampling in this study was the secondary school rather than individual students. This means therefore that each school was considered as one sub-group. The school sample was drawn through multi-stage sampling, from 18 Old Category National schools situated in Nairobi, Central Kenya, Rift Valley and Nyanza regions of Kenya. National Schools were used in the study since they are well endowed with teaching and learning resources and have
similar admission criteria. As mentioned in Section 1.10, these schools represent the top cream of academic power in Kenya.

First, the schools were divided into four clusters according to the regions where they are located. The 18 National secondary schools were visited to ascertain their suitability for the study. The criteria for suitability included qualifications, training and performance index (mean score) of subject in Biology for the teachers in the schools. Participating schools from the four clusters were then selected by purposive sampling after identifying schools categorised as boys only schools or girls only school. Purposive sampling was used to select the schools that finally constituted the sample of the study. The schools that were included in the sample fulfilled the following conditions:

i. Had not taught the topic ‘Enzymes’ within the period scheduled for the study.

ii. Were willing to cooperate with the researcher and support the research work.

iii. Were willing to adhere to the procedure and process related to the use of Sequential Teaching Methods in their respective schools.

One school from Nairobi region and another from Rift Valley region had covered the topic halfway and were thus unsuitable for the study. Similarly, one other school from Nairobi region was excluded from the study because it was uncooperative. The procedure for selection involved the use of Table of Random Numbers for those that remained on the list after excluding the ones that were found unsuitable for the study. From the two gender strata, four boys schools and four girls schools were randomly selected making a total sample of eight schools.

The regional distribution of selected schools is shown in Table 3
Table 3: Regional Distribution of Selected Schools

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of schools selected</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
</tr>
<tr>
<td>Nairobi</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Central Kenya</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rift valley</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Nyanza</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

The eight (8) schools were then randomly assigned to treatment and control groups. This was done to ensure initial equivalence between groups. Although random assignment is not a perfect method for assuring treatment group equivalence, it is nonetheless, the best method available (Sekaran & Bougue 2011). Since most Old category National schools have more than 4 Form One streams, all the streams were given the same treatment or control conditions due to ethical reasons. However, only one stream from each school was randomly sampled for analysis.

3.5.2 Sample Size

The actual schools sample consisted of eight Old Category National schools (four boys and four for girls). A participant sample of 402 learners was purposefully identified from the school sample as explained in section 3.5.1. The reason was to cater for both gender and regional representation (see Table 4).
The sample size was determined by the enrollment in the schools selected. The selection was done on the basis of location, syllabus coverage, willingness to cooperate and gender balance. Since gender was an aspect to be investigated, four of these schools were boys only schools while the other four were girls only schools. Fraenkel and Wallen (2000) recommend at least 30 subjects per group. The sample size as shown in Table 4 was thus adequate for the study.

In addition, only teachers who had undergone the SMASSE inservice training programme were selected. This selection criteria was used to control for the extraneous variables of teacher qualification and inservice training which in turn affect teachers ability and competence. The researcher trained the teachers prior to administration of treatment conditions. Each teacher was then provided with a teaching manual designed by the researcher. The teachers were also given other teaching and learning resources, that were used in the application of STM.

The researcher used non-random selection of students to the groups since classes in secondary schools exist as intact groups. The students were not randomly assigned to treatment and control groups. School authorities do not usually allow the classes to be dismantled and reconstituted for research purposes (Fraenkel and Wallen, 2000). Finally, the
researcher randomly assigned the intact groups that were chosen to the various treatment conditions. This is in line with Borg and Gall’s, (1989) recommendation that random assignment controls for interaction, maturation and selection.

3.6 Instrumentation

In this study four tools were used for data collection. One pre-test BAT was adopted but two of these were adapted from previous research by Esra, Ijlal and Ocak (2009). A description of the ready-made research instruments is made in section 3.6.1.

3.6.1 Research Instruments

i. Pre-test BAT

This tool was an adoption of the test developed by Esra, Ijlal and Ocak in 2009. The test items exhaustively covered the topic ‘enzyme activity’. The Pre-test BAT (Appendix I) whose duration was one hour, and taken individually contained 25 multiple choice items, each with five distractors. Each test item carries one mark; a maximum score of 25 marks. The test was scored using a marking scheme (see Appendix XI). Scores were expressed as a percentage since that is the culture in the Kenyan school system.

ii. Post-test BAT

The Post-test BAT (Appendix II) was similar to the pre-test BAT except for the order of questions. The test was also taken by individual learner and scored using a marking scheme (see Appendix IX). Scores were expressed as a percentage.

iii. The Biology Knowledge Retention Test (BKRT)

The BKRT (Appendix III) was designed by changing the order of the test items in the post Test BAT. It was administered 40 days after the post-test BAT. BKRT was also taken by
individual learners over a duration of one hour. It was scored using marking scheme (see Appendix X). The scores were expressed as a percentage.

iv. Transfer Test/ Concept Map

Transfer test was not structured as BAT since learners were examined on their ability to construct Concept Maps by themselves. The Concept Maps were constructed using the 29 concepts that formed the basis of the 25 items that were contained in the pre-test BAT, post-test BAT and BKRT. The concepts included: Enzymes, nomenclature, inhibitors, co-factors, coenzymes, prosthetic groups, inorganic ions, substrate, concentration, temperature, saliva, amylase, digestion, enzyme action, competitive inhibition, non-competitive inhibition, product, activation energy, pH, catalase, lipase, proteases, carbohydrases, active site, apoenzymes, hydrolysis, catalysis, hydrogen peroxide and, lock and key. The concepts were to be arranged on the basis of hierarchy, correctness of position, and linkage with correct proposition in the correct direction. The 29 concepts were generated by the researcher and given to the learners by the teachers in a stipulated time of one hour. The scoring of the Concept Maps was done according to the criteria suggested by Novak and Gowin (1984). Table 6 gives details of the criteria.

Table 5: Criteria for Scoring Concept Maps

<table>
<thead>
<tr>
<th>Item</th>
<th>Points to award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of concepts</td>
<td>Two points for every concept</td>
</tr>
<tr>
<td>Hierarchy</td>
<td>Ten points for location of concepts according to their degree of proximity on the Concept Map.</td>
</tr>
<tr>
<td>Correctness of proposition</td>
<td>Two points for correct proposition between the concepts</td>
</tr>
<tr>
<td>Accuracy of proposition</td>
<td>Two points for accuracy of proposition between the concepts</td>
</tr>
<tr>
<td>Direction of proposition</td>
<td>Two points for correct understanding of the relationship between concepts when read in the</td>
</tr>
</tbody>
</table>
direction mentioned in the proposition.

Cross – links

Every cross link between the concepts was scored over ten points according to its correctness and accuracy.


The maximum score for each of the six items in Table 6 is 58, 10, 56, 56, 56, and 10 respectively; the maximum overall score is therefore 246 points that were expressed as a percentage.

The rationale behind choice of this test was that the concepts relate to the questions in the BAT and BKRT. Furthermore, 29 concepts which were expected to be incorporated in the Concept Maps formed the basis for the 25 items that were contained in the BAT and BKRT.

The Concept Map scores were expressed as a percentage. Scores were scaled in order to comment on them easily. The scale of 1-4 was used for grading and the scores distributed as follows 1 = 1% to 25%, 2 = 26% to 50%, 3 = 51% to 75% and 4 = 76% to 100%. Grading of test scores was useful in ranking and reporting of learners’ performance. The scale represented performance quartiles. The frequency (rate of use) of each concept in the map was also determined to evaluate retrieval of information.

3.6.2 Pilot Study

The researcher carried out a pilot of the research instruments in order to establish their suitability to a Kenyan sample. The BAT and BKRT were both adopted from previous research. Furthermore, the previous study by Esra, Ijlal and Ocak (2009) was carried out on university students as opposed to secondary school students; the subjects in the current study. The pilot was conducted in two schools drawn from the Old Category National schools in
Kenya (see Appendix VII). It involved one boys-only school and one girls-only school for gender balance. However, the two schools did not take part in the treatments using STM.

3.6.3 Validity of Research Instruments

The researcher established content validity of all the instruments. This was done through construction of a Table of Test Specification. The Table of specification ensured that all content areas as well as various levels of knowledge and skills were covered by the test. The specifications of content as well as the kinds of knowledge and skills that were tested and the learning domain covered in the BAT and BKRT are presented in Table 5.

Table 6: Table of Item specification of the BAT and BKRT

<table>
<thead>
<tr>
<th>Knowledge and skills (mental and manual) and No. of items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content covered</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Meaning</td>
</tr>
<tr>
<td>Characteristics</td>
</tr>
<tr>
<td>Lock &amp; key</td>
</tr>
<tr>
<td>Hypothesis</td>
</tr>
<tr>
<td>Active sites</td>
</tr>
<tr>
<td>Enzyme groups</td>
</tr>
<tr>
<td>Catabolic reactions</td>
</tr>
<tr>
<td>Anabolic reactions</td>
</tr>
<tr>
<td>Effect of</td>
</tr>
<tr>
<td>temperature</td>
</tr>
<tr>
<td>Effect of PH</td>
</tr>
<tr>
<td>Substrate</td>
</tr>
<tr>
<td>concentration</td>
</tr>
<tr>
<td>Enzyme</td>
</tr>
<tr>
<td>concentration</td>
</tr>
<tr>
<td>Enzyme inhibition</td>
</tr>
<tr>
<td>Enzymeco-factors</td>
</tr>
<tr>
<td>Uses of Enzymes</td>
</tr>
<tr>
<td>Laboratory</td>
</tr>
<tr>
<td>experiments</td>
</tr>
</tbody>
</table>
Catalase Enzyme

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>

The BAT was also used as a pre-test before application of the Sequential Teaching Methods treatment.

The content or construct validity of the pre-test and post-test BATs was checked by experts from the School of Education, Pwani University. The experts were asked to give their opinion on the BATs’ ability to test what it supposed to test. They also checked to see if the researcher had taken all precautions in selecting the test correctly by analysing the syllabus, to cover each objective of the course. The experts found both pre-test and post–test BAT to be suitable instruments to use in collecting the data.

The validity of the concept maps was checked by experts from the School of Education, Pwani University and Centre for Mathematics and Science Teacher Education in Africa (CEMASTEA). The criteria involved checking on six aspects: the number of concepts heirachy, correctness of proposition, accuracy of proposition, direction of proposition and cross-links.

3.6.4 Reliability of Research Instruments

The pre-test BAT, post-test BAT and BKRT were adopted instruments used by Esra, Ijlal and Ocak (2009) and the reliability coefficient was 0.82 when the tests were administered to the Artuk University students. However, the researcher checked for reliability on the local scenario to check suitability. The first test was done on the pre-test BAT. This tool was adopted for the current study without any amendments to it.

The reliability of pre-test BAT was therefore examined through the interim consistency reliability test.
The Kuder- Richardson formula \(20(\text{KR}_{20})\) was applied:

\[
\text{K.R}_{20} = \frac{k}{k-1} \left[1 - \frac{\sum P^2}{\sigma^2}\right]
\]

Where; \(k\)=number of items in the test

\(\sum\)=summation of

\(P\)=proportion of the responses to one item which is correct

\(q\)= proportion of the responses to one item which is wrong

\(\sigma^2\)= variance of scores on the test

The formula was used to relate the first pilot test and the second pilot test

The \(\text{K.R}_{20}\) Value obtained by use of this formula was 0.8. This shows that the test items have a very high consistency in scoring of all the 25 items. The rationale for using \(\text{K.R}_{20}\) was to take into account the variability in the difficulty level of the test items.

Sekaran & Bougie (2011) state that this measure is indicative of the homogeneity of items in the test that tap the construct. In other words, the items should “hang together as a set” and be capable of independently measuring the same concept.

Secondly, the reliability of BKRT was determined by establishing the error variability resulting from the change in the order or sequence of the questions. This parallel form reliability was necessary since the BKRT was obtained from BAT by rearranging the order of questions.

The reliability of post –test BAT and BKRT involved finding the correlation coefficients for the two tests that were given in succession using the given formulae:
Where:

\[ r_{xy} = \frac{\sum xy}{\sqrt{\sum x^2 \sum y^2}} \]

\[ r_{xy} = \text{Correlation between } x \text{ and } y \]

\[ \sum = \text{Sum of} \]

\[ xy = \text{product of the deviation of the two sets of scores from their respective means} \]

Therefore a correlation coefficient between post-test BAT and BKRT was found to be 0.74. According to Ashworth (1982), a correlation coefficient of 0.70 is reasonably reliable. Therefore the two tools were suitable for the study.

The reliability of concept maps was established by finding the correlation coefficient of BKRT scores and the concept map scores using the formulae:

\[ r_{xy} = \frac{N \sum xy - (\sum x)(\sum y)}{\sqrt{[N \sum x^2 - (\sum x)^2][N \sum y^2 - (\sum y)^2]}} \]

Where:

\[ \sum = \text{Sum of} \]

\[ xy = \text{product of the deviation of the two sets of scores from their respective means} \]

\[ N = \text{Number in sample} \]

\[ x = \text{raw scores of first test (BKRT)} \]

\[ y = \text{raw scores of second test (concept maps)} \]

Thus a reliability coefficient of 0.76 was established. Fraenkel and Wallen (2000) point out that a correlation value of 0.70 and above is considered suitable to make inferences that are
accurate. A sample of 10 randomly picked concept maps was used with their corresponding BKRT scripts.

3.7 The Development and Use of Instructional Materials

The researcher constructed a guiding manual for the teachers use during the treatment period (Refer to Appendix IV). The content used for class instruction was developed based on the revised KIE Biology syllabus (2006). The manual also contained the content that all the learners were taught during treatment. Teachers who were involved in administering sequential teaching methods used the manual throughout the entire treatment period. The teachers in Biology for the experimental groups were trained on how to use the manual for a period of one week. After training, the pre-test was given by the teachers to all the four groups. The treatment period lasted two weeks as per the time allocated for the topic on enzymes in the syllabus (KIE, 2006). At the end of the treatment period, a post-test was administered by the teachers to all the four groups. The procedure for data collection is described in section 3.8.

3.8 Data Collection Procedure

Research authorisation (see Appendix X) was granted by the National Council for Science and Technology (NCST) now, the National Commision of Science Technology and Innovations (NACOSTI). The researcher also sought permission to collect data from schools in advance by writing to the Management of each school (See the sample of the letter, Appendix IX).

Data for this study was collected between May and July 2013. In the first week, the researcher introduced all the four (4) groups of students to Concept Maps. The teachers in Biology attended the sessions only as observers. The purpose was for expert training of students on how to construct Concept Maps. At this stage learners were shown how to draw
Concept Maps using a previously learned topic, “Chemicals of Life”. The goal was to familiarise the students with Concept Maps. A different but related topic was used so as to avoid pre-empting what students were to be assessed on.

Concept Mapping was not part of treatment to be given to experimental groups but rather a skill that students were supposed to learn so as to transfer knowledge of the topic as per the context of this study. The construction of Concept Maps requires the learner to think on a deeper cognitive level than a “Fill in the blank” test would urge (Barenholz & Tamir, 1992). However, Concept Maps could not be required/made if students had not been given opportunities to learn to make and use them as a tool to represent students’ knowledge (See Appendix IV). The researcher also trained the teachers in Biology on how to administer the treatment. Each trained teacher was provided with a teaching manual with content of the topic and other teaching and learning resources. In addition, the pre-test BAT was administered by teachers to the four groups of learners in order to determine homogeneity in their knowledge of the topic “Enzymes,” as well as similarity in learning ability. Treatment was given over a period of two weeks and was administered by the teachers on the topic “Enzymes”.

In order to collect data to address objective 1, a post test BAT was administered by teachers immediately after treatment. Each learner was provided with an answer sheet and asked to draw a line through or circle around the letter representing the answer they would have selected. Marking was done by teachers using a Marking Scheme (see Appendix X). The rationale for the post-test BAT was to collect numerical and quantitative data from the learners.

Objective 1 sought to compare the effects of different sequences of STM on achievement. All the 25 multiple choice questions tested knowledge of facts about enzymes as well as ability to
solve problems related to enzyme action. BAT post-test was used to obtain raw test scores as a measure of achievement (Refer to Appendix VI). BAT was a one hour sit-in individual test.

In order to collect data to address Objective 2, a Biology Knowledge Retention Test (BKRT) was administered by teachers 40 days after administration of the BAT post-test. BKRT was also a one hour sit-in individual test. This was to gather numerical and quantitative data from the learners.

Objective 2 sought to compare knowledge retention of different sequences of STM. BKRT had the same items and response format as BAT, the only change being order or sequence of questions. Similarly, BKRT was used to obtain raw test scores as a measure of retention (Refer to Appendix VI). According to Sisson, Swartz and Wolf (1992), knowledge retention rate is highest (>85%) immediately after learning but generally falls to 75% of its original level 3 months after original learning. Therefore 1½ months is assumed optimum period for assessing short-term retention of knowledge and expecting more than 85% level of retention.

Objective 3 sought to compare differential effectiveness of STM to transfer of knowledge. Data for addressing objective 3 was collected using Concept Maps. Transfer in Biology knowledge on the topic of Enzymes to Concept Maps was thus evaluated immediately after the Retention Test. Transfer Test involved construction of Concept Map by each student. The rationale was to obtain numerical and quantitative data from the learners. Learners were given a list of 29 concepts on the topic enzymes and asked to use these concepts to construct Concept Maps. Although time consuming, construct-a-map-from-scratch technique was considered suitable in order to expose the knowledge structure of the students. These Concept Maps were scored by the researcher using a marking scheme (see Appendix IX).
Concept Maps scores were collected from assessment of Concept Maps. The Concept Map test scores were therefore a measure of transfer of knowledge (Refer to Appendix VI).

3.9 Data Analysis and Presentation Methods

Data analysis is presented according to hypotheses. The scoresheets for the pre-test, BAT, BKRT and Transfer Test (see Appendix VI) were all checked and edited for accuracy and consistency. They were categorised according to groups. Data coding was done to conceal identity of study groups. Finally, tabulation was done by arranging data collected into concise and logical order.

The analysis involved one-way and two-way Analysis of Variance (ANOVA), using the univariate general linear model. This type of ANOVA was suitable for estimating the effect of multiple independent variables such as teaching methods on one dependent variable such as achievement. The method was used to assess the mean differences between the four groups. Nassiuma and Mwangi (2004) affirm that ANOVA is a useful technique in research where multiple sample cases are involved. In this study, the three groups constituted treatment cases and one was a control group, while the variables under investigation were achievement, retention and transfer of knowledge. Gender-based test scores were also compared using an independent sample t-test. This was to establish whether there were any differences in performance between the male and female students. The Null Hypotheses were tested at the 0.05 significance level. Data collected in this study was analysed based on the respective study hypotheses as follows:

\[ H_0: \text{There is no difference in achievement in Biology when learners are taught using different sequences of lecture, demonstration and experiment methods.} \]

Descriptive statistics calculated for observations and measures at the pre-test and post-test stage of the quasi-experimental design were means and standard error. The
inferential statistics used to examine hypothesis Ho1 was Two-way analysis of variance (ANOVA). Tukey’s post-hoc comparisons were also done in order to determine where the difference in means between groups had occurred since they were statistically significant. The statistical results of hypothesis testing and confidence intervals are presented in Chapter Four.

Ho2: There is no difference in retention in Biology when learners are taught using different Sequences of Teaching Methods (STM). Data consisted of scores on BKRT. The Means and standard error calculated from the raw scores of the BKRT constituted the descriptive statistics. A Two-way ANOVA was used in data analysis Tukey’s post-hoc comparisons were carried out to show mean separation in order to determine where the significance in difference between the means had occurred.

Ho3: There is no difference in knowledge transfer when learners are taught using different sequences of teaching methods. Data consisted of scores on TT. The Concept Maps test scores expressed as a percentage were used to obtain descriptive statistics in form of the means and standard error of the 4 groups. A one-way and two-way ANOVA was used in data analysis since the interaction of teaching method and gender showed significant difference. Tukey’s post-hoc comparisons were also carried out to examine where the differences were statistically significant.

Ho4: There is no sequence of STM that had the greatest effect on achievement, retention and transfer of knowledge. Ho4 was tested using data that comprised scores of the BAT, BKRT and the Concept Maps. The adjusted means for each group were compared to establish whether there was one that had the most effect on performance improvement. Data presentation method adopted in this study involved use of tables as seen in Chapter Four. Table 7 gives a summary of methods used in data analysis.
<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Independent variable</th>
<th>Extraneous variables</th>
<th>Dependent variables</th>
<th>Method of analysis and statistical test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ho1 There is no statistically significant difference in achievement in Biology when learners are taught using different sequences of lecture, demonstration and experiment methods.</td>
<td>Sequential teaching methods (ELD, LDE, DEL)</td>
<td>Gender</td>
<td>Achievement test scores</td>
<td>Two-way ANOVA, Post-hoc comparison and One-way ANOVA</td>
</tr>
<tr>
<td>Ho2 There is no statistically significant difference in retention in Biology when learners are taught using different sequences of lecture, demonstration and experiment methods.</td>
<td>Sequential teaching methods (ELD, LDE, DEL)</td>
<td>Gender</td>
<td>Retention test scores</td>
<td>Two-way ANOVA and Post-hoc comparison</td>
</tr>
<tr>
<td>Ho3 There is no statistically significant difference in knowledge transfer when learners are taught using different sequences of lecture, demonstration and experiment methods.</td>
<td>Sequential teaching methods (ELD, LDE, DEL)</td>
<td>Gender</td>
<td>Transfer test scores</td>
<td>Two-way ANOVA, Post-hoc comparison and One-way ANOVA</td>
</tr>
<tr>
<td>Ho4 There is no one sequence of STM that has the greatest effect on achievement, retention and transfer of knowledge.</td>
<td>Sequential teaching methods (ELD, LDE, DEL)</td>
<td>Gender</td>
<td>Biology Achievement Test scores BKRT scored and Concept Maps scores</td>
<td>One-way ANOVA</td>
</tr>
</tbody>
</table>

3.10 Logistical and Ethical considerations

The participants, having exercised the choice to participate in the study, cooperated fully in the entire task and took part in the experiment. Since most old National schools have six Form One streams, all the streams in the school were given similar treatment or control conditions for purposes of uniformity so as to counteract the feeling of discrimination. This means that all the Form One streams in the sampled schools were involved in the study.
However, only one stream was selected for analysis. The procedure involved use of Table of
Random Numbers in which the last digit was selected. During the experimental period, every
effort was made in such a way that students were able to cover their syllabus and achieve the
topic objectives as stated in the school curriculum. Students did not feel disadvantaged for
having taken part in the study. All information collected from them was kept confidential.
The researcher ensured protection of child rights to Information, Education and
Communication (IEC) during the study.

3.11 Summary

The methodology described in this chapter lays foundation for the procedures and tools that
were used in capturing data that was vital for addressing the research problem. The chapter
covered sample, research instruments, data collection and data analysis. The analysis method
used in this study was multivariate analysis using t-test, One-way and Two-way ANOVA.
The results of the analysis are presented, interpreted and discussed in Chapter Four.
CHAPTER FOUR

RESULTS, INTERPRETATION AND DISCUSSIONS

4.0 Introduction

This chapter presents the results and interpretation of the analyses, and discussions of key findings of the investigation. The chapter begins with a highlight of results of the pre-test, for ease of understanding, the results are presented both objectivewise and hypothesiswise concomitantly under the sub-headings derived from them. The results are then discussed in the light of the interpretation and literature review. The chapter concludes with a brief summary.

4.1 Results of the Pre-test

The results of performance in the Pre-test BAT administered to all the four groups prior to the experiment are presented in Table 8.

Table 8: Performance means of Four Groups Subjected to the Pre-test BAT

<table>
<thead>
<tr>
<th>N</th>
<th>Grp</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>1</td>
<td>13.8</td>
<td>4.76</td>
</tr>
<tr>
<td>97</td>
<td>2</td>
<td>12.54</td>
<td>5.25</td>
</tr>
<tr>
<td>104</td>
<td>3</td>
<td>13.00</td>
<td>4.69</td>
</tr>
<tr>
<td>99</td>
<td>4</td>
<td>12.24</td>
<td>4.57</td>
</tr>
</tbody>
</table>

In order to compare the means of the four groups, one–way ANOVA was applied. The ANOVA results of the Pre-test BAT scores are summarised in Table 9.
Table 9: Results of one-way ANOVA for the four groups subjected to pre-test BAT

<table>
<thead>
<tr>
<th></th>
<th>ss</th>
<th>df</th>
<th>ms</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>140.02</td>
<td>3</td>
<td>46.68</td>
<td>2.01</td>
<td>0.112</td>
</tr>
<tr>
<td>Within Groups</td>
<td>9242.38</td>
<td>398</td>
<td>23.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9382.41</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An examination of results in Table 9 shows that the mean scores of groups 1, 2, 3, 4 on Pre-test BAT are not significantly different (F (3,398)=2.01, p>0.05). The four groups were therefore at a comparable level of prior knowledge. An independent-samples t test was applied to compare the means of male and female students on the Pre-test BAT.

4.1.1 Performance by Gender in Pre-test BAT

Results of the analysis of are presented in Table 10.

Table 10: Independent Samples t-Test of the Pre-Tes t on BAT on Students’ Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>Mean</th>
<th>Std. Dev</th>
<th>t. Value</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>12.47</td>
<td>6.38</td>
<td>0.12</td>
<td>0.90</td>
</tr>
<tr>
<td>Female</td>
<td>13.34</td>
<td>5.38</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Male, N= 207; Female, N= 195

An independent samples t- test comparison of the mean scores of male and female learners found no significant difference between the means of the two groups (t(400) =0.12, p>.05). The mean of male learners (m=12.47, sd=6.38) was not significantly different from the mean of female learners (m=13.34, sd=5.38). The implication is that both the male and female learners were similar with respect to prior knowledge of the topic and were thus suitable for the study. This could have also implied that both boys and girls had similar learning ability.
However, the standard deviations are about 50% of the mean because learners had not been taught the topic yet hence low mean score.

4.2 Results of Post-test BAT, BKRT and TT

This section presents the results objectivewise. The results are based on students’ performance on Biology Achievement Test (BAT), Biology Knowledge Retention Test (BKRT) and the Transfer Test (TT).

4.2.1 Results of the Post–test with respect to Objective 1: Effects of Sequential Teaching Methods (STM) on Learners’ Achievement of Knowledge in Biology

It was necessary to find out the effect of teaching methods and gender as well as their interaction on achievement. A two-way Analysis of Variance (ANOVA) was thus used. The analysis of effect of STM in relation to gender are based on mean scores of Post-test BAT for the four groups. The results are presented in Table 11.

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>SS</th>
<th>df (N-I)</th>
<th>MS</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching Methods</td>
<td>14654.41</td>
<td>3</td>
<td>4884.80</td>
<td>55.70</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender</td>
<td>10101.65</td>
<td>1</td>
<td>10101.65</td>
<td>115.19</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender x Teaching Method</td>
<td>1004.18</td>
<td>3</td>
<td>334.73</td>
<td>3.817</td>
<td>0.010</td>
</tr>
<tr>
<td>Error</td>
<td>34551.35</td>
<td>394</td>
<td>87.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>958272.00</td>
<td>402</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A two-way ANOVA was computed to compare the achievement scores of the four groups that were taught using different sequences of teaching method: ELD, LDE, DEL and OOL. A
significant difference was found among the sequences of teaching methods (F(3,394)=55.70, P<.05). A significant difference was also found between male and female learners (F(1,394)=115.19, P<.05). The teaching method therefore had significant effect on achievement. This also means that there is a significant effect of gender on achievement. The interaction of teaching method with gender similarly had a significant effect F(3,394)=3.82, P<.05). The null hypothesis which stated that, there is no statistically significant difference in achievement in Biology when learners are taught using different sequences of lecture, demonstration and experiment methods was thus rejected.

Additionally, the mean scores of the pre-test and post-test were compared using a paired t-test. The purpose was to establish whether there was a significant mean gain in post-test scores over pre-test scores as shown in Table 12.

<table>
<thead>
<tr>
<th>Table 12: Comparison of the Pre-test and Post-test Mean Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Pre-test Score</td>
</tr>
<tr>
<td>Post-test Score</td>
</tr>
</tbody>
</table>

Table 12 shows that the pre-test average was 12.91, with a standard deviation of 4.84. The achievement average was 47.20, with a standard deviation of 12.49.

A paired samples t-test was calculated to compare the mean pre-test score to the mean achievement test score. The results are presented in Table 13.

<table>
<thead>
<tr>
<th>Table 13: Paired-Samples t-test of Pre-test and Post-test Mean Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
</tr>
<tr>
<td>Pre-test Score</td>
</tr>
<tr>
<td>Post-test Score</td>
</tr>
</tbody>
</table>


The results in Table 13 show a significant increase from pre-test to post-test \((t(401)=60.56, p<.05)\).

Further analysis of the pre-test and post-test mean scores also revealed that all the experimental groups (1, 2 and 3) and the control group (4) gained significantly from the teaching. However, the experimental groups whose learners were taught using the Sequential Teaching Methods (STM) had by far, a higher mean gain than the control group whose learners were taught using the oral-only lecture method. This meant that, there was a highly significant overall effect of treatment. It also suggested that, there was at least some significant difference among possible comparisons of two means in the four groups. This result strengthens the position that the STM led to higher achievement than the control condition.

However, as Sekeran and Bougie (2010) observed, when significant differences among groups are indicated by the F statistic, there is no way of knowing from only the ANOVA results where the differences lie. That is, whether the significant difference is between groups 1 and 2, or between 2 and 3, or 1 and 3. There was therefore need to find out where this experimental effect had exactly occurred. Tukey’s HSD was used to determine the nature of differences between the various sequences of teaching methods (STM). This was a better choice for determination, rather than multiple t tests, taking two groups at a time which, lowers the confidence level.

The results of mean separation using Tukey’s Post Hoc comparison are presented in Table 14.
Table 14: Tukey’s Post Hoc Comparison of the Achievement Test Scores on BAT

<table>
<thead>
<tr>
<th>Group(I)</th>
<th>Group (J)</th>
<th>N(I)</th>
<th>Mean Score</th>
<th>Mean Diff (I-J)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>102</td>
<td>46.55± 1.123</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-2.65</td>
<td>.083</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-8.76</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>-</td>
<td>9.13</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>97</td>
<td>49.20± 1.213</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>-</td>
<td>13.61</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>-</td>
<td>22.12</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>104</td>
<td>55.31± 1.321</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>-</td>
<td>17.89</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>99</td>
<td>37.41± 1.112</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The results show that all the groups had statistically significant differences in post-test scores except for groups 1 & 2 where the post-test scores were not significant. The P-value of 0.083 is greater than the acceptable 0.05. The results also showed that group 3 (DEL) had the highest achievement score at 55.31 compared to group 2 (LDE) and group 1 (ELD) whose means scores were 49.20 and 46.55 respectively. Group 4 (Control group) had the lowest mean score at 37.41.

Since the interaction of teaching method and gender was significant as shown in Table 11, it was prudent to perform one-way ANOVA for each gender separately. Table 15 shows mean scores while ANOVA results are summarised in Table 16.

Table 15: Means of Achievement Score for Male Learners Only

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std.Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52</td>
<td>42.77</td>
<td>10.53</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
<td>45.60</td>
<td>10.42</td>
</tr>
<tr>
<td>3</td>
<td>52</td>
<td>47.92</td>
<td>7.58</td>
</tr>
<tr>
<td>4</td>
<td>58</td>
<td>32.83</td>
<td>8.50</td>
</tr>
<tr>
<td>Total</td>
<td>207</td>
<td>41.89</td>
<td>10.97</td>
</tr>
</tbody>
</table>
A one-way ANOVA was computed to compare achievement scores of male learners who were taught using different Sequences of teaching methods. A significant difference was found among the different sequences of teaching ($F(3,203)=28.32, p<.05$).

Tukey’s HSD was used to determine the nature of the differences between the sequences of teaching methods among the male learners only as shown in Table 17.

**Table 16: One-Way ANOVA of Achievement Scores for Male Learners Only**

<table>
<thead>
<tr>
<th></th>
<th>Ss</th>
<th>Df</th>
<th>Ms</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Btw Groups</td>
<td>7315.66</td>
<td>3</td>
<td>2438.55</td>
<td>28.32</td>
<td>.000</td>
</tr>
<tr>
<td>Within Grp</td>
<td>17478.00</td>
<td>203</td>
<td>86.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24793.66</td>
<td>206</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 17: Tukey’s HSD Comparisons of Achievement Scores for Male Learners Only**

<table>
<thead>
<tr>
<th>Group (I)</th>
<th>Group (J)</th>
<th>N(I)</th>
<th>Mean Score (I)</th>
<th>Mean Score (I-J)</th>
<th>Diff</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>52</td>
<td>42.77±1.46</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-2.83</td>
<td>10.53</td>
<td>.440</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-5.15</td>
<td>9.94</td>
<td>.026</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>9.94</td>
<td></td>
<td>.000</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>45</td>
<td>45.60±1.55</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-2.32</td>
<td>10.42</td>
<td>.609</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>12.77</td>
<td></td>
<td>.000</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>52</td>
<td>47.92±1.05</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>7.58</td>
<td></td>
<td>.000</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>58</td>
<td>32.83±1.12</td>
<td>-</td>
<td>15.10</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.50</td>
<td></td>
</tr>
</tbody>
</table>
The analysis in Table 17 revealed that male learners who were taught using OOL scored lowest (m=32.83, sd=8.50) than the rest and the difference was statistically significant. A significant difference was also found between DEL (m=47.92, sd=7.58) and ELD (m=42.77, sd=10.53). However, there was no significant difference between the male learners who were taught using ELD and LDE (m=45.60, sd=10.42), and also between DEL and LDE. On the other hand, the descriptive statistics for female learners only are presented in Table 18 as means and standard deviation while the ANOVA results are summarised in Table 19.

**Table 18: Means of Achievement Scores for Female Learners Only**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std.Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>51</td>
<td>50.43</td>
<td>8.77</td>
</tr>
<tr>
<td>2</td>
<td>51</td>
<td>52.39</td>
<td>10.95</td>
</tr>
<tr>
<td>3</td>
<td>52</td>
<td>62.69</td>
<td>6.22</td>
</tr>
<tr>
<td>4</td>
<td>41</td>
<td>43.90</td>
<td>11.47</td>
</tr>
<tr>
<td>Total</td>
<td>195</td>
<td>52.84</td>
<td>11.51</td>
</tr>
</tbody>
</table>

**Table 19: One-Way ANOVA of Achievement Score for Female Learners Only**

<table>
<thead>
<tr>
<th></th>
<th>SS</th>
<th>df</th>
<th>Ms</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Btw Groups</td>
<td>8628.72</td>
<td>3</td>
<td>2876.24</td>
<td>32.18</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>17073.35</td>
<td>191</td>
<td>89.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>25702.07</td>
<td>194</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results in Tables 18 and 19 compare the achievement score of female learners who were taught differently using STM. A significant difference was found among the different sequences of STM ( F(3,191)=32.18, p<.05). The significant difference necessitated post-hoc comparisons of the Tukey’s HSD, whose results are shown in Table 20.
Table 20: Tukey’s HSD Comparisons of Achievement Scores for Female Learners Only

<table>
<thead>
<tr>
<th>Group (I)</th>
<th>Group (J)</th>
<th>N(I)</th>
<th>Mean (I)</th>
<th>Score (I-J)</th>
<th>Mean SD (I-J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>51</td>
<td>50.43±1.23</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td>-1.96</td>
<td>.722</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td>-12.61</td>
<td>.000</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td>6.53</td>
<td>.006</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>51</td>
<td>52.39±1.53</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td>-10.30</td>
<td>.000</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td>8.50</td>
<td>.000</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>52</td>
<td>62.69±0.86</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td></td>
<td></td>
<td>18.79</td>
<td>.000</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>41</td>
<td>43.90±1.792</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The results in Table 20 show that there is a significant difference in achievement scores of female learners among all groups except those who were taught using ELD (m=50.43, sd=8.77) and LDE (m=52.39, sd=10.95).

The results in Tables 11 up to 20 all based on Objective 1 point to the following findings:

i. The use of STM led to improved achievement in knowledge in Biology compared to use of oral-only lecture method.

ii. DEL sequence led to the highest mean score on achievement test.

iii. Gender had a significant effect on achievement, with female learners achieving higher scores than male learners.

iv. Interaction of teaching method (STM) and gender also had significant effects on achievement of knowledge.

These findings are discussed in section 4.3.1
4.2.2 Results of BKRT with Respect to Objective 2:

Effects of Sequential Teaching Methods (STM) on Learners’ Retention of Knowledge in Biology

It was necessary to find out the effect of teaching methods and gender as well as their interaction on the retention of knowledge. The measure of retention is the score obtained on BKRT. The results of a two-way (ANOVA) of effect of interaction between STM, and gender, based on mean scores of the BKRT for the four groups are presented in Table 21.

Table 21: Two-Way ANOVA of Effect of Teaching Methods and Gender on Retention

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Ss</th>
<th>Df (N-I)</th>
<th>Ms</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching Method</td>
<td>23829.82</td>
<td>3</td>
<td>7943.27</td>
<td>85.26</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender</td>
<td>7062.98</td>
<td>1</td>
<td>7062.98</td>
<td>75.81</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender interacting with Teaching Method</td>
<td>521.43</td>
<td>3</td>
<td>173.81</td>
<td>1.87</td>
<td>0.135</td>
</tr>
<tr>
<td>Error</td>
<td>36708.61</td>
<td>394</td>
<td>93.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>974080</td>
<td>402</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A two-way ANOVA was computed to compare retention scores of the four groups, that were taught using different sequences of STM: ELD, LDE, DEL, and OOL. A significant effect was found among the sequences of STM (F(3,394)=85.26,p<.05). The interaction between teaching methods and gender had no significant effect on retention of knowledge (F=(3,394)=1.87,p<.05). The null hypothesis which stated that ‘there is no statistically significant difference in retention in Biology when learners are taught using different sequences of lecture, demonstration and experiment methods’ was thus rejected.

The results of ANOVA suggest that the treatment had significant overall effect. The results also indicate significant difference between treatment groups. It was thus necessary to
perform Tukey's post hoc comparisons to determine where the differences exactly occurred.

The results of mean separation are presented in Table 22.

**Table 22:** Tukey’s Post Hoc comparison of the retention test scores on the BKRT.

<table>
<thead>
<tr>
<th>Group (i)</th>
<th>Group (j)</th>
<th>n(i)</th>
<th>Mean score (i) ± SD (i)</th>
<th>Mean diff (i-j)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>102</td>
<td>45.65 ± 1.321</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-3.92 ± 0.721</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-12.43 ± 2.231</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>-</td>
<td>9.69 ± 0.721</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>97</td>
<td>49.57 ± 1.311</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>-</td>
<td>8.51 ± 0.721</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>-</td>
<td>13.61 ± 0.721</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>104</td>
<td>58.08 ± 1.145</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>-</td>
<td>22.12 ± 3.145</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>99</td>
<td>35.96 ± 1.211</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The results show that there was significant difference between group means. That is, the retention mean score of groups 1, 2, 3 and 4 were all different at 0.05 level. Group 3 (DEL) had the highest retention score at 58.08 compared to group 2 (LDE) and group 1 (ELD) whose means scores were 49.57 and 45.65 respectively. Group 4 (Control) had the lowest mean at 35.96. Since the interaction of teaching methods and gender was not significant, there was no need to perform a one-way ANOVA for each gender separately.

The results in Tables 21, and 22 based on Objective 2 point to the following findings:

i. The use of STM led to improved retention of knowledge compared to use of oral-only lecture method.

ii. DEL sequence mean scores were highest on BKRT

iii. Gender had significant effect on retention with female learners scoring higher than their male counterparts.

iv. Interaction of teaching method (STM) and gender showed no significant effect on retention of knowledge.

These findings are discussed in section 4.3.2
4.2.3 Results of Transfer Test with Respect to Objective 3:
Effects of Sequential Teaching Methods on Transfer of Knowledge in Biology

The results of analysis of effects of STM in relation to gender based mean scores of the transfer test for the four groups are presented in Table 23.

Table 23: Two Way ANOVA of Effects of Teaching Method and Gender on Transfer

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>SS</th>
<th>df(N-I)</th>
<th>MS</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching Methods</td>
<td>51985.77</td>
<td>3</td>
<td>17328.59</td>
<td>215.71</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender</td>
<td>61500.49</td>
<td>1</td>
<td>61500.49</td>
<td>765.56</td>
<td>0.000</td>
</tr>
<tr>
<td>Teaching Method</td>
<td>7707.82</td>
<td>3</td>
<td>2569.27</td>
<td>31.98</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender Interacting</td>
<td></td>
<td>394</td>
<td>80.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>402</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A two-way ANOVA was computed to compare Concept Map scores of the four groups that were taught using different sequences of STM; ELD, LDE, DEL and OOL. A significant difference was found among the sequences of STM (F(3,394)=215.71,p<.05). The teaching method (treatment) had significant effect on transfer of knowledge. A significant difference was also found between male and female learners (F(1,394)=765.56,p<.05). The interaction effect of teaching method and gender also had significant effect on transfer of knowledge F(3,394)=31.98, p<.05). The null hypothesis which stated that, ‘there was no
statistically significant difference in knowledge transfer when learners are taught using different sequences of lecture, demonstration and experiment methods’ was thus rejected.

Both STM and gender, as well as gender interacting with STM significantly affected transfer of knowledge. It was thus necessary to carry out mean separation to determine exactly where the differences lay. Tukey’s Post-Hoc comparisons were used to ascertain where the differences actually occurred as shown in Table 24.

Table 24: Tukey’s Post-Hoc Comparison of the Transfer Test Scores

<table>
<thead>
<tr>
<th>Group(i)</th>
<th>Group (j)</th>
<th>n(i)</th>
<th>Mean score (i)</th>
<th>Mean diff (i-j)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>102</td>
<td>30.11± 1.211</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-10.63</td>
<td>.000</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-23.59</td>
<td>.000</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>-</td>
<td>8.58</td>
<td>-</td>
<td>.000</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>97</td>
<td>40.74± 1.146</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-12.96</td>
<td>.000</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>-</td>
<td>19.22</td>
<td>-</td>
<td>.000</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>104</td>
<td>53.70± 1.123</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>-</td>
<td>32.18</td>
<td>-</td>
<td>.000</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>99</td>
<td>21.53± 1.131</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Post-hoc comparison of the four groups show statistically significant difference in the mean scores of all the four groups at p=0.05. The results in Table 24 show that Group 3 (DEL) had the highest transfer score at 53.70 followed by group 2 (LDE) and group 1 (ELD) whose mean scores were 40.74 and 30.11 respectively.

Since the interaction of teaching methods and gender was significant, it was necessary to perform one-way ANOVA for each gender separately. Table 25 shows the descriptive results in form of means and standard deviation while ANOVA results are summarised in 26.
Table 25: Descriptives of Transfer Scores for Male Learners Only.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52</td>
<td>10.73</td>
<td>6.23</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
<td>32.38</td>
<td>8.56</td>
</tr>
<tr>
<td>3</td>
<td>52</td>
<td>43.40</td>
<td>9.43</td>
</tr>
<tr>
<td>4</td>
<td>52</td>
<td>11.69</td>
<td>9.96</td>
</tr>
<tr>
<td>Total</td>
<td>207</td>
<td>23.91</td>
<td></td>
</tr>
</tbody>
</table>

Table 26: One-Way ANOVA of Transfer Score for Male Learners Only

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>ms</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>40682.69</td>
<td>3</td>
<td>13560.23</td>
<td>178.78</td>
<td>.000</td>
</tr>
<tr>
<td>Within groups</td>
<td>15397.74</td>
<td>203</td>
<td>95.85</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

56078.44  206

The one-way ANOVA was computed to compare the transfer of knowledge score of male learners who were taught differently using STM. A significant difference was found among the different sequences of teaching (F (3,203) =178.78, p<.05). Tukey’s HSD was used to determine the nature of the difference between the four sequences of teaching methods among the male learners only as shown in Table 27.
Table 27: Tukey’s HSD Comparison of Transfer Scores for Male Learners Only

<table>
<thead>
<tr>
<th>Group (i)</th>
<th>Group(j)</th>
<th>n(i)</th>
<th>Mean score(i)</th>
<th>Std dev</th>
<th>Mean difference(i-j)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>52</td>
<td>10.73±863</td>
<td>6.23</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-21.65</td>
<td>.000</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-32.67</td>
<td>.000</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-.959</td>
<td>.939</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>45</td>
<td>32.38±1.277</td>
<td>8.56</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-11.03</td>
<td>.000</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20.69</td>
<td>.000</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>52</td>
<td>43.40±1.308</td>
<td>9.43</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>.000</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>58</td>
<td>11.69±1.147</td>
<td>9.96</td>
<td>31.71</td>
<td>-</td>
</tr>
</tbody>
</table>

The results in Table 27 revealed that the male learners who were taught using ELD and OOL scored lowest (m=10.73, sd=6.23; m=11.69, sd=9.96) respectively. Male learners who were taught using DEL scored highest (m=43.40, sd=9.43) than male learners who were exposed to LDE (m=32.38, sd=8.56). Male learners who were taught using ELD and those exposed to OOL (m=11.69, sd=9.96) but all others were significantly different.

On the other hand, the descriptives for female learners only are presented in Table 28 as mean scores and standard deviation while the ANOVA results are summarised in Table 29.

Table 28: Means of Transfer Score for Female Learners Only

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>51</td>
<td>49.92</td>
<td>10.02</td>
</tr>
<tr>
<td>2</td>
<td>51</td>
<td>48.27</td>
<td>10.26</td>
</tr>
<tr>
<td>3</td>
<td>52</td>
<td>64.00</td>
<td>8.59</td>
</tr>
<tr>
<td>4</td>
<td>41</td>
<td>35.44</td>
<td>7.42</td>
</tr>
<tr>
<td>Total</td>
<td>195</td>
<td>50.20</td>
<td>13.49</td>
</tr>
</tbody>
</table>

Table 29: ANOVA of Transfer Scores for Female Learners Only

<table>
<thead>
<tr>
<th></th>
<th>SS</th>
<th>Df</th>
<th>Ms</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>19029.26</td>
<td>3</td>
<td>6343.09</td>
<td>74.54</td>
<td>.000</td>
</tr>
<tr>
<td>Within groups</td>
<td>16253.94</td>
<td>191</td>
<td>85.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>35283.20</td>
<td>194</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The results in Table 28 and 29 compare the transfer scores of the female learners who were taught differently using STM. A significant difference was found among the different sequences of STM (F(3,191) =74.54, p<.05.

Tukey’s HSD was used to determine the nature of the differences among the groups taught using STM. The results of mean separation for transfer test scores of female learners are shown in Table 30.

**Table 30: Tukey’s HSD Comparisons of Transfer Scores For Female Learners Only**

<table>
<thead>
<tr>
<th>Group (i)</th>
<th>Group(j)</th>
<th>n(i)</th>
<th>Mean score(i)</th>
<th>Std dev</th>
<th>Mean difference(i-j)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1 51</td>
<td></td>
<td></td>
<td>49.92±1.403</td>
<td>10.02</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1 2 - 51</td>
<td></td>
<td></td>
<td>48.27±1.437</td>
<td>10.26</td>
<td>-</td>
<td>.804</td>
</tr>
<tr>
<td>1 3 - 52</td>
<td></td>
<td></td>
<td>64.00±1.192</td>
<td>8.60</td>
<td>-</td>
<td>.000</td>
</tr>
<tr>
<td>1 4 - 41</td>
<td></td>
<td></td>
<td>35.44±1.159</td>
<td>7.42</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 2 51</td>
<td></td>
<td></td>
<td>48.27±1.437</td>
<td>10.26</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 3 - 52</td>
<td></td>
<td></td>
<td>64.00±1.192</td>
<td>8.60</td>
<td>-</td>
<td>.000</td>
</tr>
<tr>
<td>2 4 - 41</td>
<td></td>
<td></td>
<td>35.44±1.159</td>
<td>7.42</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 3 52</td>
<td></td>
<td></td>
<td>64.00±1.192</td>
<td>8.60</td>
<td>-</td>
<td>.000</td>
</tr>
<tr>
<td>3 4 - 41</td>
<td></td>
<td></td>
<td>35.44±1.159</td>
<td>7.42</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The results in Table 30 showed that female learners who were taught using OOL scored lower (m=35.44, sd=7.42) than those who were taught using ELD (m=49.92, sd=10.02). Female learners who were exposed to DEL scored highest (m=64.00, sd=8.60). All the sequences of teaching methods yielded transfer scores that were statistically different except for ELD (m=49.92, sd=10.02 and LDE (m=48.27, sd=10.26).

The results in Tables 23, 24,25,26,27,28,29 and 30 based on Objective 3 yielded the following findings:

i. The use of STM led to increased transfer of knowledge in Biology compared to the use of oral-only lecture method.

ii. DEL sequence yielded the highest mean score on transfer test
iii. Gender had significant effect where females did better than male learners.

iv. The interaction effect of STM and gender had significant effect.

These findings are discussed in section 4.3.3
4.2.4 Results of Comparison of Achievement, Retention and Transfer of Knowledge

The results are given with respect to Objective 4 as well as Hypothesis 4 (H₀₄) which stated that there is no sequence of STM that has the greatest effect on achievement, retention and transfer of knowledge in Biology. To test this hypothesis, Biology Achievement Test scores, retention test scores and transfer test scores of the four groups were compared. Table 31 shows results of comparison of the three sets of test scores.

Table 31: Results of Comparison of post-test BAT, BKRT and Concept Maps

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Achievement BAT Mean Score</th>
<th>Retention BKRT Mean Score</th>
<th>Transfer TT Mean score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>102</td>
<td>46.55</td>
<td>45.65</td>
<td>30.11</td>
</tr>
<tr>
<td>2</td>
<td>97</td>
<td>49.20</td>
<td>49.57</td>
<td>40.74</td>
</tr>
<tr>
<td>3</td>
<td>104</td>
<td>55.31</td>
<td>58.08</td>
<td>53.70</td>
</tr>
<tr>
<td>4</td>
<td>99</td>
<td>37.41</td>
<td>35.96</td>
<td>21.53</td>
</tr>
<tr>
<td>Total</td>
<td>402</td>
<td><strong>47.12</strong></td>
<td><strong>47.32</strong></td>
<td><strong>36.52</strong></td>
</tr>
</tbody>
</table>

Results in Table 31 show that group three (DEL) had the highest mean scores on all the variable of achievement, retention and transfer at 55.31, 58.08 and 53.70 respectively. Group two (LDE) was the second with mean scores on the same variables as 49.20, 49.57 and 40.74 respectively. Group one (ELD) was third with 46.55, 45.65 and 30.11 respectively. Finally group four (OOL) had the lowest mean scores at 37.41, 35.96 and 21.53 respectively. The null hypothesis which stated that; there is no sequence of STM that has the greatest effect on achievement, retention and transfer of knowledge in Biology was thus rejected.

The results in Table 31 based on Objective 4 point to the following findings:

i. Group three (DEL) had the highest mean scores on achievement, retention and transfer of knowledge in Biology.
ii. Group four (OOL) meanscores were lowest on all the three variables of achievement, retention and transfer of knowledge

These findings are discussed in section 4.3.4

4.3 Discussion of Results

This section is organised under subheadings generated from the objectives of the study. The discussion on findings of this study is as follows:

4.3.1 Findings based on Objective 1:

Effect of STM on Student’s Achievement in Biology

A comparison of groups 1, 2, 3 and 4 students’ pre-test BAT mean scores showed non-significant differences $F(401) = 2.01$, $p > 0.000 < 0.05$ significant level (Table 8). This result indicates that the four groups were similar in their prior knowledge of the topic: ‘Enzymes’ before the treatment started. The four groups were thus suitable for the study. Administering pre-test was necessary because knowledge discrepancy among learners has been identified as influencing effectiveness of instructional design (Mayer & Moreno, 2002). The four groups were thus homogenous.

However the results of achievement test indicate that students who were taught through the STM achieved significantly higher scores in post test BAT than those taught using the oral-only lecture method (Table 12). This then implied that the STM was more effective in enhancing students’ achievement than the oral-only lecture method. The significant effect of STM over oral-only lecture method could be attributed to involvement of multimedia. STM is perhaps most effective due to its ability to satisfy the many types of learning preferences that a particular type of learners embody.
The findings of this study are supported by Reigeluth’s (1979) elaborations theory which, provides a broad perspective framework for selecting and sequencing the content in instructional setting. Reigeluth (1979), proposed two fundamental types of sequencing strategies in teaching that is, topical and spiral sequencing. Both involve mastering a topic or task in several phases such as STM while using different ways. Wilson and Cole (1992) made recommendations for restructuring Reigeluth’s elaboration theory giving rise to a new approach: SCM (Simplifying Conditions Method).

Reigeluth (1999) further proposed a specific method to provide practical guidelines for organising holistic sequences of instruction. The major contribution of Reigeluth’s theory to STM is the guidance for scope and sequence decisions for heuristic tasks, using heuristic task analysis methods. According to Keller’s ARCs model of motivational design (1987), effective instructional design should provide variability to better reinforce materials and account for individual differences in learning styles. Use of a variety of methods in presenting material such as STM is thus encouraged. Sequential teaching methods seen to represent a learning cycle or spiral where the learner “touches all the bases”. The learner is provided with opportunities to experience, reflect, think and act or do. The net effect is enhanced original learning characterized by creation of significant new knowledge.

4.3.1.1 Gender-based Effect of Concept Mapping on Achievement in Biology

All groups were exposed to Concept Mapping whose effect is likely to have had more positive impact on girls than boys (Table 10). Previous study by Namasaka, Mondoh and Keraro (2013) showed that girls are more motivated when they are taught using Concept Mapping strategy. The effect of Concept Mapping done during treatment would thus be responsible for significant difference in gender scores on achievement. Girls performed better than boys in all the four groups. Previous research by Moir and Jessel (1997), revealed
that girls see more, and remember in detail more of what they see. This could imply that,
gender disparity in performance which is caused by gender differences in organisation and
the mechanism of learning could be resolved using the Concept Mapping technique. The
differences in brain organisation, published works by White (1987), Branford and Cocking
(1999) and John (2003) provide an explanation for female superiority in Concept Mapping
and consequently achievement. According to Canas & Novak (2005) and Prezzler (2004),
Concept Mapping is all about relationships between concepts that indeed form the basis for
Biology Education (Novak, 1998). It is therefore emphasised that establishing the impact of
gender difference on learning through Concept Mapping is important. The idea that females
achieve better when exposed to Concept Maps fits in our knowledge of female brain.
According to Moir & Jessel, (1997), the female mind is organised so as to place primacy on
relationships. Additionally, the female mind model connects a far wide variety of related
pieces of information, against a background where the importance of relationships is
paramount.

The learning differences between two gender is a natural phenomenon. Gender-based
disparities could be addressed if these differences are recognised and understood.
Furthermore, female and male attitude have both biological and social roots (Kimura &
Harshman, 1984). The social roots are easy to alter but not the biological ones. Knowing this
could be the first step to bridging gender gap in learning. Science is doing what it can, by
producing the evidence that the minds of male and females are different (Moir &Jessel,
1997).

Witheston (1985) studied how boys and girls respond to visual messages and found out that
girls have their responses residing in both left and right sides of the brain. The study revealed
that the difference relates to the corpus collosum, bundle of fibres that link the left and right
side of the brain. It allows for exchange of information between the left and right side of the
brain. Consequently, in girls, the nerve fibre is thicker and more bulbous than in boys. The key message – exchange centre is bigger in girls than in boys. This implies that the two sides of the brain have a larger number of connections in girls. It also means that more information is exchanged between the left and right sides of the female brain. Later research by Moir & Jessel (1997) showed that, the more the connections individuals have, the more articulate and fluent they are in logical and sequential thought processes such as Concept Mapping.

### 4.3.1.2 Effect of STM Interacting with Gender on Achievement

Gender is a factor of learning whose significant influence cannot be ignored. According to works by John (2003) and Moir & Jessel (1997) both genders are born with brains wired in different ways. The male and female learners therefore, think in different ways, have different strengths, value things in different ways and use different strategies to learning in particular. However, females are easily visually distracted than males but absence of visual distraction heighten performance of other senses of touch, taste, smell and hearing.

Findings of this study heightens the awareness of gender disparity in performance as a matter of differential brain operations in organisation of learning. Showing that females achieve more than males when using Concept Maps may be unpopular and controversial. However, most studies on gender and achievement show that on average girls do better in schools than boys (Bhavnani & Hutt, 1972; National Centre for Education Statistics; 2003).

### 4.3.2 Findings based on Objective 2:

**Effects of STM on Students’ Retention of Knowledge in Biology**

Aziz (1990) perceives retention as storage, the process of holding encoded information in memory. The results presented in Table 21 show that students who were taught through the
STM had significantly higher scores in the Biology Knowledge Retention Test (BKRT) than those taught using the oral-only lecture method. This therefore, implied that the STM was more effective in enhancing students’ retention of knowledge than the oral-only lecture method. STM ensures maximum utilisation of most parts of the memory. The study also sought to determine the best sequence of the STM that would lead to highest retention levels. To address this, students’ retention of content material relative to the three sequences was analysed. The analysis of results indicated that the students who were taught through the DEL sequence obtained significantly higher scores in the BKRT than those who were taught through the LDE and ELD sequences. Perhaps DEL provides the best pattern for elaborative rehearsal of information. DEL seems to enhance attention to information while in the working or short term memory. Sisson et al (1992) provide literature on clinical information with regard to knowledge retention of material taught and examined in Biology. However, the history of research on retention is fairly recent. It is rather unfortunate that in education a great deal of time and effort is devoted to the acquisition of knowledge but very little is known about how long this knowledge is retained. Addressing this issue has practical relevance to educational policy and practice. It also has implications for theoretical models of memory and knowledge representation.

The first attempt to address the issues about the retention of formally acquired knowledge was reported by Bahrick (1984). He found a strong relationship between retention and the initial depth of learning. Nevertheless, his study laid a strong foundation upon which subsequent researches were conducted in various specific disciplines, Biology Education included. Results of a study done by Esra et al. (2009), focusing on effects of STM on retention in Biology, showed higher retention level in lessons beginning with experiment or slide demonstration as opposed to lecture method. Their findings agreed with results of previous researches that laboratory work offer students hands-on-experience thus enhancing
their remembrance to 90%. Similarly the present research findings agree with Esra’s slide demonstration but differ on the aspect of experiment. Esra et al. (2009) reported that student comprehension is enhanced with lesson started with experiment, because laboratory activities increase students’ interest in the topic. They seem not to have taken into account the impact of the nature of knowledge as well as its representation. Maslow’s Theory of learning highlighted the differences between experimental knowledge, procedural knowledge, theoretical and spectator knowledge. Similarly, the difference in learner’s retention may not only be in the method but also in the dimension or domain of knowledge. For example, dimensions or domains of knowledge in Biology include Anatomy, Physiology, Morphology and Histology. The most effective method is one that can represent the specific domain of knowledge in a transparent manner for learners to see.

In the present study, animated slide demonstration is a more effective instructional compliment for teaching processes or mechanisms in Biology. This view is strongly supported by O’Day (2009), who observed that on retention, animated slide demonstration rival and at times surpass the pedagogical value of lab work. This is true especially when dealing with knowledge that involves a physiological process or mechanism.

The aspect that needs to be addressed is: How students could learn about the mechanism of enzyme action through laboratory work and what the students were supposed to observe. It was not enzyme activity itself but rather mere effect of enzyme activity. Pedagogically, learning about enzyme action can only be inferred through experiment. Animated slide demonstration therefore, provided for direct observation of the mechanism, hence better understanding and higher retention.

Inquiry-based laboratory approaches are more effective than verification approaches (Opara 2011). In this study, start of lesson with experiment was probably less effective because it
focused on verification as opposed to discovery of concepts and observation of actual mechanism of enzyme activity.

Since the KICD encourage use of a combination of methods, then DEL would be the best option. The findings of this study show that it is particularly effective if animated slide demonstrations are introduced to students in the classroom before going to the laboratory to verify and then finally summarise main points of the topic with a lecture. The students may meaningfully learn through STM. A skillful coordination of DEL will increase their mutually supportive synergism thus improving their overall effectiveness. Some learning activities help students prepare for others, and the ideas-and-skills learned in earlier activities were reinforced by later experiences (Johnson, 1991). In this way, it is possible not only to increase the students’ achievement on knowledge, but also increase their levels of retention of knowledge. According to Cognitive Load Theory of learning by Sweller (1994), the human working memory has a threshold of four to ten elements making some material difficult to learn. Element interactivity refers to the degree to which the elements of some to-be-learned information can, or cannot, be understood in isolation. As a consequence of the high element inter-activity, the cognitive load induced exceeds the capacity of the working memory. Chandler and Sweller (1991) provided evidence that the cognitive load of some learning material can be greatly reduced if the information is presented pictorially as in the case of slide demonstration.

Cognitive load can either be intrinsic or extraneous. Intrinsic cognitive load is due to solely the intrinsic nature (difficulty) of some to-be-learned content. Extraneous cognitive load is due to the instructional method used to present information to learners (Chandler & Sweller, 1996).
Applying Cognitive Load Theory to teaching, learning will be maximised by ensuring that as much of a learner’s working memory as possible is free to attend only to encoding to-be-learned information. Accordingly, lecture method imposes a relatively high level of cognitive load (Sweller, 1988). On the other hand, the major weakness of laboratory experiments in teaching a psychological process such as enzyme action is that learners may successfully carry out the practical, yet effectively learn nothing. Slide demonstration impose very low levels of cognitive loads thus facilitate learning (Mousavi, Low & Sweller, 1995). While use of DEL sequence provided an effective alternative to both LDE and ELD sequences, it can be argued that perhaps DEL fosters original learning, which in turn is determinant of retention. This effect could be attributed to reduced cognitive load when visual presentations (animations) are used in the beginning. In conclusion, DEL sequence has been demonstrated to be highly effective at improving retention of psychologically based content such as enzyme activity in Biology. The association between concepts and the motion in the graphic is clearly indicated in slides. This is necessary for construction of meaning.

The laboratory work and class experiments have a redundancy effect since they only show the presence of catalase enzyme in cells, effects of pH and temperature on enzyme activity, but do not show the typical or real mechanism of enzyme action on substrate to yield products. Use of DEL is thus encouraged since it also has a positive effect on transfer of knowledge in Biology (see the subsequent section for a detailed explanation of this subject).

4.3.2.1 Gender-based Effect on Retention of Knowledge in Biology

The results of this study indicate that there is a significant difference in retention of knowledge between male and female learners at .05 level. This could be attributed to the difference in original learning as reflected in achievement scores. A comparison between mean scores of male and female learners on both BAT and BKRT reveal that female learners
scored significantly higher than their male counterparts. The effect of original learning was therefore positively carried forward to the retention of knowledge. Based on gender effect of Concept Mapping as described in section 4.3.1.1, it appears that female learners process chunks of information more suitably and meaningfully. This ensures that the information is retained for a longer time and can be used in different situations of life (Mundal 2013). The researcher observes that Concept Mapping technique could be responsible for helping female learners to build a frame of concepts that are retained over longer periods. Although a few studies have been undertaken to investigate gender-based effect on retention of knowledge, so far scanty literature is available. The present study therefore attempted to bridge the knowledge gap on gender differences in retention of knowledge of Biology.

4.3.2.2 Effect of STM Interacting with Gender on Retention of Knowledge

The results showed that although both STM and gender separately had significant effect on retention but the interaction between the two indicated that there was no significant effect (see Table 13). The findings also revealed that different versions of STM differ with respect to their effect on retention of knowledge in Biology. Furthermore the female gender appeared to retain more of the knowledge learned. The insignificant interaction effect of STM and gender could be attributed to other factors beyond the scope of the present study. It could perhaps be due to the nature in Biology subject, which includes many abstract concepts, events, sub-topics and facts that students have to learn. These, according to Cimer (2004) and Trumper (2006), pose learning difficulties at individual learners level.
4.3.3 Findings based on Objective 3:
Effects of STM on Students’ Transfer of Knowledge in Biology

Transfer of knowledge mainly depends on concept formation because these concepts are the basic building blocks of the structure of the learners knowledge. In addition, Concept Mapping provides opportunity for transfer of knowledge in a new context of assessment. This was a major departure from the study done by Esra, Ijlal & Ocak (2009), which only focused on effect of STM on students’ achievement and retention in Biology thus providing no information about whether the acquired and retained knowledge could be transferred to other contexts. Concept Maps made by students in this study were used as transfer test.

The results show that the students who were taught through the DEL sequence obtained significantly higher scores in the TT than those who were taught through the LDE and ELD sequences (Table 24). Cognitive Load Theory displays strong constituencies with the findings of the current study regarding effective teaching sequence (DEL). While information processing models of learning have historically emphasised the “fixed” limits of working memory, there is evidence (Pavio, 1990; Baddeley, 1992) to show that under certain conditions, an expansion of working memory may be achieved. This may only be achieved by engineering reduced levels of extraneous cognitive load through instructional design. The bottom line, according to cognitive load theory, will often be the need to decrease total cognitive load, and the need to maximise cognitive resources available for use in the learning process (Pavio, 1990). If for some reason cognitive load increases instead of decreasing, then learning will be inhibited. This explanation attests to the findings of this study. Whereas both slides demonstration and laboratory experiments methods involve visual aids, but experiments increase cognitive load.
Additionally, laboratory work on enzyme action has a redundancy effect since learners do not see the actual mechanism in play. They only infer from the results of the experiments since the actual process is hidden. Experiments also impose a split attention effect as well as modality effect. However, the researcher still holds the view that experiments are more effective for explicit information such as anatomy but not for hidden information as is the case in physiology.

On the other hand, slide demonstration has shown to be highly effective at facilitating learning of physiologically based content. Cognitive Load Theory explains this result by focusing on the levels of cognitive load imposed upon the student who needs to process the varying subject content. Consequently, slides are fully self-contained (O’Day, 2008). Furthermore, slides eliminate split attention leaving learners to concentrate their attention / observation wholly on the projection screen. The success of this theory in developing effective teaching strategies is of paramount importance to educationalist, teachers and curriculum developers. The findings of this study therefore contribute to the body of evidence and knowledge to show that students taught using DEL sequence are actually more able to deal with the issue of transfer of knowledge to new contexts as attested to by their superior performance on transfer test using Concept Mapping technique.

Results reveal animated slide demonstration is more effective if used prior to experiment and lecture. This could be attributed to the ability of slides to represent knowledge of mechanism of enzyme action in a way that learners can understand. Animated slides are effective knowledge representation tools which enable learners to ‘mentally’ see the knowledge depicted as a process. Knowledge on enzyme action is factual information which when acquired in a context of meaningful learning is not only retained longer, but can be transferred in other contexts to solve new problems (Brawsford et al, 199). Research done by (Sweller, 1994; O’Day, 2008) support the view that use of slide demonstration helps to make
the instruction “conceptually transparent” to students. They are metacognition tools that easily convey information to learners through a process called mental modeling (Borich; 2004). Mental modeling helps the learners to internalise, recall and then transfer knowledge to different contexts at a later time. The importance of exploring the issue of transfer of knowledge arise from the finding that knowledge is retained particularly well when it is actively employed in practical work (Neisser, 1984).

4.3.3.1 Effect of Gender on Transfer of Knowledge in Biology

The result of the analysis showed that gender has a significant effect on transfer of knowledge in Biology. Female learners were found to have significantly higher transfer scores than their male colleagues. Furthermore Concept Mapping technique appeared to be favourables to girls as compared to boys. The findings of the present study corroborates those of another study by Namasaka, Mondoh and Keraro (2013). In Concept Mapping female learners get an opportunity to exploit there superior inherent functioning abilities of their memory. As such the female learner is enabled to retain and transfer larger amounts of information.

4.3.3.2 Interaction Effect of STM and Gender on Transfer of Knowledge in Biology

Transfer of knowledge requires retrieval, which involves the process of locating, removing and using information stored in memory. According to Cimer(2012), students must learn to transfer what they have learned and it is the teacher’s duty and responsibility to teach students how to transfer learning to other situations.

The results of the present study show significant effect of interaction between STM and Gender. In accordance with the goals of teaching Biology, students need opportunities to apply their knowledge in new situations. Studies done by Mondal (2013) and Aziz(1990) show that there is consistent gender differences in the recall and transfer of
episodic memories. Females tend to recall and transfer those with an emotional flavour (particularly positive) than males do. There exists sex differences in the role of amygdale in forming and retrieving of episodic memories. This could be applied in the teaching-learning situation. The effects of STM as revealed by the findings of this study could be attributed to the role of STM as revealed by the findings of this study could be attributed to the role of STM which include: enhancing of relearning, meaningfulness and schema formation.

4.3.4 Discussion of Findings based on objective 4
Establishment of the Sequences of STM that had greatest effect on Achievement, Retention and Transfer of knowledge

An overall finding from this study is that sequential teaching methods (STM) increase achievement, retention and transfer of knowledge in Biology. The DEL sequence of STM is the most effective relative to LDE and ELD. The use of STM should always consider adoption of the sequence that yield highest scores on achievement, retention and transfer test.

The DEL sequence was the best alternative since it yielded the highest achievement scores on BAT, highest retention scores on BKRT and similarly highest transfer score on TT (Concept Maps). As such, Demonstration-Experiment-Lecture (DEL) sequence is identified as the most effective in comparison to LDE and ELD.

4.4 Summary

Since the theory of teaching is yet to be developed, the present study indicates some new focus towards the application of sequential methods of teaching Biology and its impact on variables like achievement, retention and transfer of knowledge. It has helped to shed new light on the paradox of teaching Biology. Too much premium is paid on use of laboratory work as the most effective teaching method without regard to the nature of knowledge being
learned. The current study has shown that commencing teaching with demonstration had greatest impact on performance improvement thus playing the role of an advance organiser.
CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

The purpose of the study was to evaluate differential effectiveness of three versions of Sequential Teaching Methods namely; ELD, DEL and LDE. The instruments used for Data Collection were: BAT pre-test, BAT post-test, BKRT and Concept Maps.

This chapter presents a summary of the findings study, and the conclusions drawn from the study. It also gives implications of the study and recommendations. In addition, areas for further research are suggested.

5.1 Summary of Main Findings and Contributions to Knowledge

On the basis of the data analysis presented in Chapter 4 the following are the major findings of the study:

1. The use of STM led to improved achievement in knowledge in Biology compared to the use of oral-only lecture. Furthermore, there was a significant difference in student achievement in Biology between learners taught using different sequences of STM. In addition, Demonstration (animated slides)-Experiment-Lecture (DEL) sequence yielded the highest mean score on achievement. This is attributed to the “conceptual transparency” which demonstration provides to learners at the beginning of the topic. Students’ understanding is then deepened and broadened using experiment for verification and lastly, by making a conclusive summary using a lecture.

2. The use of STM led to improved retention of knowledge compared to the use of oral-only lecture. There was also a significant difference in students’ retention of
knowledge in Biology between students taught using different sequences of STM. Similarly as in objective one, DEL sequence results were highest (58.08%) on Biology knowledge retention test.

3. The use of STM led to increased transfer of knowledge in Biology compared to the use of oral-only lecture. There was a significant difference in students’ transfer of knowledge when students were taught using different sequences of STM.

4. The DEL sequence yielded the highest mean scores on achievement retention and transfer of knowledge at 55.31%, 58.80% and 53.70% respectively.

5.3 Conclusion

The teaching philosophy emerging from the findings of this study is that, each teaching method used yielded some amount of learning. The use of a combination of teaching methods sequentially enhances mastery and meaningful learning. This is characterised by high achievement, retention and transfer of knowledge. A combination of teaching methods is more effective due to complementarity and the supplementary role that each plays. Each method of teaching has its own strengths and weaknesses. The effects vary depending on the position of a particular method in the specific sequence of teaching. Thus the first method in the sequence determines the amount of original learning that occurs.

In conclusion, Sequential Teaching Methods (STM) when used in instruction could enhance immediate post treatment achievement test scores, retention and transfer of knowledge in Biology well over oral-only lecture method as predominantly used in Kenyan Secondary Schools. This will however, be more beneficial when the most effective sequence of STM is used in teaching.
Demonstration Experiment-Lecture (DEL) sequence has been found to be the most effective with BAT (55.31%), BKRT (58.08%) and TT (57.30%) compared with other alternate sequences and OOL.

The findings of the study support emphasis made by KIE (now KICD) that teachers in Biology should use a combination of methods on a single topic. The incorporation of STM in teaching is therefore beneficial to the pedagogical process. DEL is useful in addressing the problem of low achievement in Biology at the Kenya Certificate of Secondary Education Examinations (KCSE) and should be adopted.

5.4 Recommendations

This study has provided some insights into the need for teachers to provide students with more opportunities for meaningful learning to help them improve achievement, retention and transfer of knowledge in Biology. Thus, the recommendations below are given in the light of the findings and context of this study.

5.4.1 Recommendations at the pedagogical level

1. The KICD should formulate new policy guidelines laying emphasis on use of Sequential Teaching Methods as a means to improve learners conceptual understanding of knowledge in Biology especially that concerned with physiological processes or mechanisms such as ‘enzyme action’.

2. Universities, colleges and CEMASTEA should improve on the existing policy on implementation in Biology syllabus by training and retraining teachers on use of STM. This could be done through workshops, seminars, conferences and training programs. Animated Slide Demonstration Experiment-Lecture (DEL) sequence is highly recommended. This is likely to enhance achievement, retention and transfer, assuming that all other factors are held constant.
(3) Schools should provide facilities/equipment which are necessary for effective implementation of Sequential Teaching Methods. This is important because Biology is best taught in well equipped laboratories and students learn the subject with much ease if taught using a sequence of methods.

(4) The ministry of Education and other stakeholders should adopt a policy to provide secondary schools and universities with financial and material resources needed to effectively utilise STM. Shortage of fund, equipment and learning resource make implementation difficult.

(5) Educators should respect and embrace gender differences in achievement and adopt teaching methods which enhance the potential of female students.

(6) Universities and colleges should focus on training for innovative teaching rather than knowledge.

5.4.2 Recommendations for Further Research

The results of this study have revealed that students who were exposed to STM and especially DEL sequence performed better on achievement, retention and transfer tests in the area of Physiology.

The question that remains unanswered by the study is is how the same sequence (DEL) affects knowledge relating to Anatomy, Histology and Morphology.

The recommendation in this regard, is that research be carried out to explore the effects of STM (DEL, LDE and ELD) on achievement, retention and transfer in relation to different kinds of knowledge in Biology such as Physiology, Anatomy, Morphology and Histology. This kind of research is likely to make curriculum developers based at KICD, Quality Assurance Division of the Ministry of Education Science and Technology (MoEST) and all the stakeholders to become more aware of
the importance of using the most effective sequence of STM in the acquisition of knowledge, development of process skills as well as promotion of positive attitude towards Biology.
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APPENDICES

APPENDIX I: BIOLOGY ACHIEVEMENT TEST (BAT) – PRE- TEST

Instructions

i. Answer all questions on the question paper by circling the option which is correct.

ii. Read carefully before you make a choice of the answer

Time: 1 Hour

1.

In the graph reaction rate vs substrate concentration, the reason that the curve reaches a plateau, and does not increase any further at high substrate concentration is that:

(a) the active site is saturated with substrate

(b) there is a competitive inhibitor present

(c) there is a non-competitive inhibitor present

(d) the allosteric enzyme is locked in an inactive conformation

(e) all substrate has been converted to product
2. Which of the following is true about enzyme catalyzed reactions?

<table>
<thead>
<tr>
<th>Activation energy</th>
<th>Rate of reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Increase</td>
<td>Decrease</td>
</tr>
<tr>
<td>(b) Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>(c) Decrease</td>
<td>Decrease</td>
</tr>
<tr>
<td>(d) Stable</td>
<td>Increase</td>
</tr>
<tr>
<td>(e) Decrease</td>
<td>Increase</td>
</tr>
</tbody>
</table>

3. Many enzymes require the presence of an additional cofactor or coenzyme. Coenzymes may be covalently bound to the apo-enzyme part. Which one of the cofactor, coenzymes and apo-enzyme is always protein?

(a) only I  (b) only II  (c) only III  (d) I And II  (e) II and III

4. (I) Substrate name
   (II) Reaction name
   (III) Kind of reaction

Which of the above are used for to give a name to enzyme?

a) Only I  (b) Only II  (c) I,II,III  (d) I and II  (e) II and III

5. Which of the following is molecule of hydrolysis of all enzymes?

a) Glucose
b) Glycerin
c) Nucleotide
d) Amino acid
e) Fatty acid
6. (I) The enzyme molecules become denatured at high temperatures
   (II) Enzymes consist of a protein and a non-protein
   (III) They are taken with foods
   (IV) They can be used repeatedly
Which of the above are true for enzymes?
   a) II and III  (b) III and IV  (c) I, II and III  (d) I, II and IV
   (e) I, III and IV

7. Which of the following is not a feature of enzyme?
   a) Enzymes lower the activation energy for chemical reactions.
   b) Energy that must be added to get a reaction started, which is recovered as the reaction proceeds.
   c) Enzyme does not form chemical bonds with the substrate, it changed
   d) The activity of enzymes is strong affected by changes in pH
   e) The activity of enzymes is strongly affected by changes in temperature

8. Which of the following are not true for enzymes?
   a) The activity of enzymes is strongly affected by changes in pH
   b) A enzyme can work with various co enzymes.
   c) Enzymes can be used as ATP for enzyme-catalyzed reaction
   d) Bind their substrates at active sites
   e) The enzyme structure begins to (denature) at high temperature.

9. (I) water
   (II) Substrate surface
   (III) ATP
(IV) Temperature

Although the concentrations for enzyme and substrate are sufficient in an enzyme – catalyzed reaction, which of the above’s insufficient can be effective on the rate of reaction.

(a) Only I (b) only II (c) I and IV (d) I, II, IV (e) III, II, I

10. Enzymes have:

I apo-enzyme, II coenzyme and III cofactors

Which of the above is inorganic?

a) Only I (b) only II (c) only III (d) I and II (e) II and III

11. Which of the following denaturates the enzymes by increasing?

(I) Temperature

(II) pH

(III) Enzyme concentration

(IV) Substrate concentration

(a) I and II (b) I and III (c) III and IV (d) I, II and III (e) II, III and IV

12. The diagram shows a typical relationship between enzyme activity and:
(a) enzyme concentration
(b) substrate concentration
(c) temperature
(d) PH
(e) inhibitors

13. Enzymes
   a) Are composed primarily of polypeptides, which are polymers of amino acids.
   b) Can bind prosthetic groups such as metal ions that participate in enzyme reactions.
   c) Have defined structures
   d) Lower the activation energy for chemical reactions.
   e) All statements are true.

14. Which of the following can explanation that enzymes are specific for one particular reaction?
   a) Enzyme remains unchanged
   b) The enzyme does not form a chemical bond with the substrate.
   c) Lowering the activation energy of the reaction
   d) Lock and key relation with substrate. This specificity is due to the shapes of the enzyme molecules.
   e) They can be used repeatedly

15. Obtain three test tubes and fill 5ml of hydrogen peroxide to each tube. Crush one of the pieces of liver with a mortar and pestle and add it to one of the test tubes and add pieces of frozen liver to a second tube. Add natural pieces of liver to the third tube. It may be helpful to use a small spatula when transferring the liver to the tube. How do you put in order the tubes according to rate of reaction?
   (a) I, II, III     (b) II, I, III     (c) II, III, I     (d) III, I, II     (e) III, II, I
16. Which of the following statements about reaction rate is NOT true?

(a) Reaction rate is the speed at which the reaction proceeds toward equilibrium.
(b) Reaction rate is governed by the energy barrier between reactions and products.
(c) Enzymes can accelerate the rate of a reaction.
(d) Reaction rates are not sensitive to temperature.
(e) None of these.

17. Which of the following is true why the activity of enzymes is strongly affected by changes in pH and temperature?

(a) Most are proteins
(b) Enzymes are catalysts
(c) Enzymes contain cofactor
(d) Enzymes are catalysts
(e) Enzyme molecules are sensitive to inhibitors.

18. Obtain a test tube and put an amount of starch and then add enzymes for hydrolysis reaction. Observe the reaction. Which of the following are excepted?

(I) Starch concentration
(II) Enzyme concentration
Glucose concentration

(a) only I    (b) only II    (c) I and II    (d) I and III    (e) II and III

19. Activation energy is,

   a) Energy that must be added to get a reaction started, which is recovered as the
      reaction proceeds
   b) Difference in energy between reactants and products
   c) Energy that is lost as heat
   d) Free energy
   e) Equal to the entropy times the absolute temperature

20.

Which of the following explains above figures?

   a) Enzymes are specific for one particular substrate
   b) Enzymes are affected by changes in temperature
   c) Enzymes require the presence of an additional, non-protein, cofactor in order to work.
   d) Substrate concentration affects the rate of reaction.
   e) There is a certain temperature at which an enzyme’s catalytic activity is at its greatest

21. To overcome an energy barrier between reactants and products, energy must be provided
    to get the reaction started. This energy, which is recovered as the reaction proceeds, is called:
22. (I) Each enzyme works within quite a small pH range

(II) Enzymes have active site

(III) Enzymes required usually vitamins or made from vitamins

(IV) Enzymes contains prosthetic groups such as metal ions

Which of the following is true about enzyme catalyzed reactions?

a) Only I  
b) Only II  
c) I and II  
d) II and III  
e) II, III, IV

23. Which of the following is present on enzyme structure?

(a) amino acids  
(b) glucose  
(c) nucleic acid  
(d) nucleotide  
(e) fatty acid  
(f) II and III

24. A+B $\rightarrow$ e $\rightarrow$ C

Which of the following is required for above reaction?

(a) Water  
(b) coenzyme  
(c) cofactor  
(d) (high temperature)  
(f) ATP

25. Obtain three test tubes and fill 5 ml of hydrogen peroxide to each tube. Crush one of the pieces of liver with a mortar and pestle and add it to one of the test tubes and add pieces of
frozen liver to a second tube. Add natural pieces of liver to the third tube. It may be helpful to use a small spatula when transferring the liver to the tube. How do you put in order the tubes according to rate of reaction?

a) I, II, III  
b) II, I, III  
c) II, III, I  
d) III, I, III  
e) III, II, I

APPENDIX II: BIOLOGY ACHIEVEMENT TEST (BAT) POST-TEST

Instructions

i. Answer all questions on the question paper by circling the option which is correct.

ii. Read carefully before you make a choice of the answer

Time: 1 Hour

1. Which of the following statements about reaction rate is NOT true?

(f) Reaction rate is the speed at which the reaction proceeds toward equilibrium.

(g) Reaction rate is governed by the energy barrier between reactions and products.

(h) Enzymes can accelerate the rate of a reaction.

(i) Reaction rates are not sensitive to temperature.

(j) None of these.

2. Which of the following is true why the activity of enzymes is strongly affected by changes in pH and temperature?

(a) Most are proteins

(b) Enzymes are catalysts
(c) Enzymes contains cofactor

(d) Enzymes are catalysts

(e) Enzyme molecules are sensitive to inhibitors.

3. Obtain a test tube and put an amount of starch and then add enzymes for hydrolysis reaction. Observe the reaction. Which of the following are excepted?

(I) Starch concentration

(II) Enzyme concentration

(III) Glucose concentration

(a) only I  (b) only II  (c) I and II  (d) I and III  (e) II and III

4. Activation energy is,

(a) Energy that must be added to get a reaction started, which is recovered as the reaction proceeds
(b) Difference in energy between reactants and products
(c) Energy that is lost as heat
(d) Free energy
(e) Equal to the entropy times the absolute temperature

5 (I) The enzyme molecules become denatured at high temperatures

(II) Enzymes consist of a protein and a non-protein

(III) They are taken with foods

(IV) They can be used repeatedly

Which of the above are true for enzymes?

b) II and III  (b) III and IV  (c) I, II and III  (d) I, II and IV
6. Which of the following is not a feature of enzyme?

(a) Enzymes lower the activation energy for chemical reactions.
(b) Energy that must be added to get a reaction started, which is recovered as the reaction proceeds.
(c) Enzyme does not form chemical bonds with the substrate, it changed
(d) The activity of enzymes is strongly affected by changes in pH
(e) The activity of enzymes is strongly affected by changes in temperature

7. Which of the following are not true for enzymes?

(a) The activity of enzymes is strongly affected by changes in pH
(b) An enzyme can work with various coenzymes.
(c) Enzymes can be used as ATP for enzyme-catalyzed reaction
(d) Bind their substrates at active sites
(e) The enzyme structure begins to (denature) at high temperature.

8. Although the concentrations for enzyme and substrate are sufficient in an enzyme –catalyzed reaction, which of the above’s insufficient can be effective on the rate of reaction.

(b) Only I  (b) only II  (c) I and IV  (d) I, II, IV  (e) III, II, I
9. Many enzymes require the presence of an additional cofactor or coenzyme. Coenzymes may be covalently bound to the apo-enzyme part. Which one of the cofactor, coenzymes and apo-enzyme is always protein?

(a) only I  (b) only II  (c) only III  (d) I And II  (e) II and III

10. (I) Substrate name

(II) Reaction name

(III) Kind of reaction

Which of the above are used for to give a name to enzyme?

a) Only I  (b) Only II  (c) I,II,III  (d) I and II  (e) II and III

11. Which of the following is molecule of hydrolysis of all enzymes?

(a) Glucose  
(b) Glycerin  
(c) Nucleotide  
(d) Amino acid  
(e) Fatty acid

12. Enzymes have:

I apo-enzyme, II coenzyme and III cofactors  

Which of the above is inorganic?

b) Only I  (b) only II  (c) only III  (d) I and II  (e) II and III

13. Which of the following denaturates the enzymes by increasing?
19. Obtain three test tubes and fill 5ml of hydrogen peroxide to each tube. Crush one of the pieces of liver with a mortar and pestle and add it to one of the test tubes and add pieces of frozen liver to a second tube. Add natural pieces of liver to the third tube. It may be helpful to use a small spatula when transferring the liver to the tube. How do you put in order the tubes according to rate of reaction?

(b) I, II, III  (b) II, I, III  (c) II, III, I  (d) III, I, II  (e) III, II, I

(b) Only I  (b) only II  (c) I and II  (d) II and III  (e) II, III, IV

15. In the graph reaction rate vs substrate concentration, the reason that the curve reaches a plateau, and does not increase any further at high substrate concentration is that:

(f) the active site is saturated with substrate
(g) there is a competitive inhibitor present
(h) there is a non-competitive inhibitor present
(i) the allosteric enzyme is locked in an inactive conformation
(j) all substrate has been converted to product

16. Which of the following is true about enzyme catalyzed reactions?

<table>
<thead>
<tr>
<th>Activation energy</th>
<th>Rate of reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>(g) Increase</td>
<td>Decrease</td>
</tr>
<tr>
<td>(h) Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>(i) Decrease</td>
<td>Decrease</td>
</tr>
<tr>
<td>(j) Stable</td>
<td>Increase</td>
</tr>
<tr>
<td>(k) Decrease</td>
<td>Increase</td>
</tr>
</tbody>
</table>

17. The diagram shows a typical relationship between enzyme activity and:

(a) enzyme concentration
(b) substrate concentration
(c) temperature
18. Enzymes
(a) Are composed primarily of polypeptides, which are polymers of amino acids.
(b) Can bind prosthetic groups such as metal ions that participate in enzyme reactions.
(c) Have defined structures
(d) Lower the activation energy for chemical reactions.
(e) All statements are true.

19. Which of the following can explanation that enzymes are specific for one particular reaction?
(a) Enzyme remains unchanged
(b) The enzyme does not form a chemical bond with the substrate.
(c) Lowering the activation energy of the reaction
(d) Lock and key relation with substrate. This specificity is due to the shapes of the enzyme molecules.
(e) They can be used repeatedly

20. (I) Each enzyme works within quite a small pH range
(II) Enzymes have active site
(III) Enzymes required usually vitamins or made from vitamins
(IV) Enzymes contains prosthetic groups such as metal ions
Which of the following is true about enzyme catalyzed reactions?

a) Only I b) Only II c) I and II d) II and III e) II, III, IV

21. Which of the following is present on enzyme structure?
(a) amino acids  (b) glucose  (c) nucleic acid  (d) nucleotide  
(e) fatty acid  (e) II and III  

22. A+B  e ——> C  
Which of the following is required for above reaction?  
(b) Water  (b) coenzyme  (c) (cofactor)  (d) (high temperature) 
(l)  ATP  

23. Obtain three test tubes and fill 5 ml of hydrogen peroxide to each tube. Crush one of the pieces of liver with a mortar and pestle and add it to one of the test tubes and add pieces of frozen liver to a second tube. Add natural pieces of liver to the third tube. It may be helpful to use a small spatula when transferring the liver to the tube. How do you put in order the tubes according to rate of reaction?  
   a) I, II, III   b) II, I, III   c) II, III, I   d) III, I, III   e) III, II, I  

24.  

Which of the following explains above figures?
(a) Enzymes are specific for one particular substrate
(b) Enzymes are affected by changes in temperature
(c) Enzymes require the presence of an additional, non-protein, cofactor in order to work.
(d) Substrate concentration affects the rate of reaction.
(e) There is a certain temperature at which an enzyme’s catalytic activity is at its greatest

25. To overcome an energy barrier between reactants and products, energy must be provided to get the reaction started. This energy, which is recovered as the reaction proceeds, is called:

(a) activation energy
(b) initiation energy
(c) reaction energy
(d) kinetic energy
(e) potential energy

APPENDIX III: BIOLOGY KNOWLEDGE RETENTION TEST (BKRT)

Instructions

i. Answer all questions on the question paper by circling the option which is correct.

ii. Read carefully before you make a choice of the answer

Time: 1 Hour

1. (I) The enzyme molecules become denatured at high temperatures
(II) Enzymes consist of a protein and a non-protein
(III) They are taken with foods

(IV) They can be used repeatedly

Which of the above are true for enzymes?

a) II and III   (b) III and IV   (c) I, II and III   (d) I, II and IV   (e) I, III and IV

2 Which of the following is not a feature of enzyme?

(a) Enzymes lower the activation energy for chemical reactions.

(b) Energy that must be added to get a reaction started, which is recovered as the reaction proceeds.

(c) Enzyme does not form chemical bonds with the substrate, it changed

(d) The activity of enzymes is strongly affected by changes in pH

3. The activity of enzymes is strongly affected by changes in temperature

(I) Substrate name

(II) Reaction name

(III) Kind of reaction

Which of the above are used for to give a name to enzyme?

a) Only I   (b) Only II   (c) I,II,III   (d) I and II   (e) II and III

4 Which of the following denaturates the enzymes by increasing?

I. Temperature

II. pH

III. Enzyme concentration

IV. Substrate concentration

20. I and II(b) I and III   (c) III and IV   (d) I, II and III   (e) II, III and IV
5. Which of the following can explain that enzymes are specific for one particular reaction?

(a) Enzyme remains unchanged

(b) The enzyme does not form a chemical bond with the substrate.

(c) Lowering the activation energy of the reaction

(d) Lock and key relation with substrate. This specificity is due to the shapes of the enzyme molecules.

(e) They can be used repeatedly

6. Which of the following is present on enzyme structure?

(a) amino acids  
(b) glucose  
(c) nucleic acid  
(d) nucleotide  
(e) fatty acid (e) II and III

7. To overcome an energy barrier between reactants and products, energy must be provided to get the reaction started. This energy, which is recovered as the reaction proceeds, is called:

(a) activation energy

(b) initiation energy

(c) reaction energy

(d) kinetic energy

(e) potential energy

8. Which of the following statements about reaction rate is NOT true?

(a) Reaction rate is the speed at which the reaction proceeds toward equilibrium.

(b) Reaction rate is governed by the energy barrier between reactions and products.
(c) Enzymes can accelerate the rate of a reaction.
(d) Reaction rates are not sensitive to temperature.
(e) None of these.

9. Obtain a test tube and put an amount of starch and then add enzymes for hydrolysis reaction. Observe the reaction. Which of the following are excepted?

I. Starch concentration
II. Enzyme concentration
III. Glucose concentration

(a) only I  (b) only II  (c) I and II  (d) I and III  (e) II and III

10. Many enzymes require the presence of an additional cofactor or coenzyme. Coenzymes may be covalently bound to the apo-enzyme part. Which one of the cofactor, coenzymes and apo-enzyme is always protein?

(a) only I  (b) only II  (c) only III  (d) I And II  (e) II and III

11. Which of the following is true why the activity of enzymes is strongly affected by changes in pH and temperature?

(a) Most are proteins
(b) Enzymes are catalysts
(c) Enzymes contains cofactor
(d) Enzymes are catalysts
(e) Enzyme molecules are sensitive to inhibitors.
Which of the following explains above figures?

a) Enzymes are specific for one particular substrate  

b) Enzymes are affected by changes in temperature  

c) Enzymes require the presence of an additional, non-protein, cofactor in order to work.  

d) Substrate concentration affects the rate of reaction.  

e) There is a certain temperature at which an enzyme’s catalytic activity is at its greatest

13. A+B → C

Which of the following is required for above reaction?

(c) Water  (b) coenzyme  (c) (cofactor)  (d) (high temperature)

(m) ATP

14. Activation energy is,

(a) Energy that must be added to get a reaction started, which is recovered as the reaction proceeds  

(b) Difference in energy between reactants and products  

(c) Energy that is lost as heat  

(d) Free energy  

(e) Equal to the entropy times the absolute temperature

15. Which of the following is not a feature of enzyme?

(a) Enzymes lower the activation energy for chemical reactions.
(b) Energy that must be added to get a reaction started, which is recovered as the reaction proceeds.
(c) Enzyme does not form chemical bonds with the substrate, it changed
(d) The activity of enzymes is strong affected by changes in pH
(e) The activity of enzymes is strongly affected by changes in temperature

16. Which of the following are not true for enzymes?

(a) The activity of enzymes is strongly affected by changes in pH
(b) A enzyme can work with various co enzymes.
(c) Enzymes can be used as ATP for enzyme-catalyzed reaction
(d) Bind their substrates at active sites
(e) The enzyme structure begins to (denature) at high temperature.

17. (I) water

I. Substrate surface
II. ATP
III. Temperature

Although the concentrations for enzyme and substrate are sufficient in an enzyme – catalyzed reaction, which of the above’s insufficient can be effective on the rate of reaction.

(c) Only I  (b) only II  (c) I and IV  (d) I, II, IV  (e) III, II, I

18. Obtain three test tubes and fill 5ml of hydrogen peroxide to each tube. Crush one of the pieces of liver with a mortar and pestle and add it to one of the test tubes and add pieces of frozen liver to a second tube. Add natural pieces of liver to the third tube. It may be helpful to use a small spatula when transferring the liver to the tube. How do you put in order the tubes according to rate of reaction?

(c) I, II, III  (b) II, I, III  (c) II, III, I  (d) III, I, II  (e) III, II, I
19. Which of the following is molecule of hydrolysis of all enzymes?
   a) Glucose
   b) Glycerin
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20. Enzymes have:
    I apo-enzyme, II coenzyme and III cofactors
    Which of the above is inorganic?
   c) Only I  (b) only II (c) only III (d) I and II (e) I I and III

21. Enzymes
   a) Are composed primarily of polypeptides, which are polymers of amino acids.
   b) Can bind prosthetic groups such as metal ions that participate in enzyme reactions.
   c) Have defined structures
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   a) I, II, III b) II, I, III c) II, III, I d) III, I, III e) III, II, I
23. (I) Each enzyme works within quite a small pH range

(II) Enzymes have active site

(III) Enzymes required usually vitamins or made from vitamins

(IV) Enzymes contains prosthetic groups such as metal ions

Which of the following is true about enzyme catalyzed reactions?

a) Only I   b) Only II   c) I and II   d) II and III   e) II, III, IV

24.

The diagram shows a typical relationship between enzyme activity and:

(a) enzyme concentration

(b) substrate concentration

(c) temperature

(d) PH

(e) inhibitors

25.
In the graph reaction rate vs substrate concentration, the reason that the curve reaches a plateau, and does not increase any further at high substrate concentration is that:

(a) the active site is saturated with substrate
(b) there is a competitive inhibitor present
(c) there is a non-competitive inhibitor present
(d) the allosteric enzyme is locked in an inactive conformation
(e) all substrate has been converted to product
APPENDIX IV: STM Training Manual

This manual is designed to help teachers in Biology to implement STM on the topic “ENZYMES”. It contains the methods to be used in teaching specific content which include: Animated slide demonstration, laboratory student experiment, lecture method and Concept Mapping. These methods are in line with the requirements of the KICD curriculum and are arranged to be taught in three different sequences, namely: ELD, LDE and DEL. Several researches have shown that STM increase achievement of students in Biology hence need to use it in implementing the Kenyan secondary school curriculum. The implementation will thus mark a milestone and usher in a new era where teaching in Biology will yield meaningful learning. Concept Mapping will also be addressed. The strategy has been shown to be an effective teaching/learning as well as evaluation tool. Concept Maps will therefore be used at the end of research to assess students’ ability to transfer knowledge. The training programme using this manual seeks to empower teachers in Biology with adequate content and skills to be able to teach students according to the design prescribed for the present study. In that way, the research objectives will thus be achieved.

Theme: Fostering use of Sequential Teaching Methods and Concept Mapping in Biology.

Rationale statement for the training is guided by the following.

1. Need to enhance capacity of the teachers in Biology in order to teach the topic ‘Enzyme activity’ according to the design of the present study.

2. Use of Concept Mapping teaching/learning and evaluation strategy is relatively new to our school curriculum hence need to address it adequately.

3. Students need to be equipped further with skills in Concept Mapping so as to apply them in learning in Biology.
4. There are envisaged challenges that teachers in Biology may face in implementing STM hence need to address them in advance.

5. Need to encourage the practice of STM and Concept Mapping so that the objectives of the present study could be achieved

6. Teachers and students are both important participants in the study and will be required to teach and learn respectively hence need to further develop their T/L skills.

Objectives of Training are aimed at empowering participants to acquire knowledge and skills in the following areas:

- a) To carry out animated slide demonstration on the topic ‘Enzyme action/activity’.
- b) Design and carry out Laboratory student experiment on ‘Enzyme action/activity’.
- c) To teach using lecture method more competently.
- d) To apply the sequence of STM as per the requirements of the study.
- e) To enhance Concept Mapping skills through actualization
- f) To address challenges experienced in the implementation of STM and Concept Mapping.

**Teachers’ Guide**

By the end of the topic, the learner should be able to

- a) Define the term enzyme
- b) Identify different types of enzymes.
- c) Explain how naming of enzymes is done.
- d) Identify substrates and types of reactions for various enzymes.
- e) Describe properties of enzymes.
f) Discuss how various factors affect enzyme controlled reactions. They include: temperature, PH, specificity, substrate concentration, Enzyme concentration, co-factors co-enzymes and inhibitors.

g) Describe the process of enzyme inhibition.

h) Carry out practical activities (lab experiment) to investigate how the various factors affect enzyme activities

i) Design an experiment to investigate the presence of catalase enzyme in living tissues.

Note: refer to KLB, Sec. New Syllabus. Form one Book).

Teaching Programme

WEEK ONE

Number of lessons: 4

Activities: Pre-test BAT

  Concept Mapping- using the topic ‘chemicals of life’

  Teaching of content using STM (ELD, LDE, DEL)

  Teaching content using oral-only lecture for control group.

WEEK TWO

Number of lessons: 4

Activities: Teaching content using STM for experimental of groups.

  Teaching content using oral-only lecture for control groups

  Practice on Concept Mapping
WEEK THREE

Number of lessons: 4

Activities: Teaching content using STM and oral-only lectures for experimental groups and control groups respectively

Practice on Concept Mapping

WEEK FOUR

Number of lessons: 2. (for evaluation only)

Activities: Administering of Post-Test BAT.

Marking, scoring and recording of BAT.

AFTER 40 DAYS OF POST-TEST BAT

(About 9th week)

Number of lessons: 4

Activities: Administering in Biology Knowledge Retention test (BKRT)

Administering of transfer test (TT) by Concept Mapping.

Sequential Teaching Methods (STM)

ELD for experimental group 1a and b

LDE for experimental group 2a and b

DEL for experimental group 3a and b
Laboratory Student Experiment

This method will be used for aspects concerning enzyme activity such as observation of enzyme catalytic features, co-factors, co-enzymes and reactions between enzymes and substrates. This will be learner-centered.

Demonstration Slides

Slide demonstration method will involve use of animated slides about enzyme structure and functions; lock and key hypothesis and effects of various factors on enzyme structure. This will be teacher-centered.

Lecture Method

This method will be used to cover relevant theory of enzymes. This will be teacher-learner-centered activity. Teacher explanation of key concepts and their relationships will dominate the session.

Oral - only Lecture Method

This will be applied to control group only. All the content covered under the topic ‘enzymes’ will be taught by lecture only.

CONCEPT MAPPING FOR TEACHING IN BIOLOGY

Concept Mapping in Biology

Rationale

Teachers have many strategies at their disposal, many of which have been used to enhance the quality in Biology during the teaching/learning process. Concept Mapping is a valuable
strategy in the biology classroom that can be applied to planning and preparation, teaching, learning, revision, summarizing and assessment. However, this strategy remains rarely used, if ever. The purpose of this session is to explore the various applications of Concept Mapping and adapt them to the various situations related to the teaching/learning in Biology.

Session objectives

By the end of the session the participant should be able to:

1) Explain Concept Mapping as a tool in the teaching/learning process in biology
2) Construct Concept Maps in given topics.
3) Identify the challenges that teachers may face in using Concept Mapping and suggest ways to overcome the challenges.

Introduction

Concept Maps have been used successfully to promote meaningful learning and effective teaching and are helpful in representing qualitative aspects of students’ learning. The whole idea of Concept Mapping is based on the assertion that human beings are meaning makers and thus the human brain endeavors to construct order from apparent chaos.

A Concept Map is a visual, structured representation of concepts and their interrelationships while Concept Mapping is the process that involves identification of concepts in a body of study materials and the organization of those concepts into hierarchical arrangements from the most general, most inclusive to the least general, most specific. The key concepts in a Concept Map are linked with lines bearing propositions (logical connectives).
The concepts can be represented using:

- Colour coding for different concept types
- Various shapes of concept boxes

Concept Maps provide teachers with an avenue for developing insight into student understanding as evidenced by well-organized and richly elaborated knowledge structures, valid propositional relationships and interrelationships. They also help to identify errors, omissions or misconceptions.

Simple Concept Maps consists of two or three concepts linked by propositions.

Example of Concept Maps

**Figure 4: Formation of Proteins**

```
Proteins → Made of → Amino acids
```

**Figure 5: A food chain**

```
Grass → Eaten by → Antelope → Eaten by → Lion
```
Figure 6: A Concept Map on animals

Animals

Can be or Can be

Invertebrate

Vertebrate

Can be or Can be

Arthropods

Cold blooded

Warm blooded

Can be

Can be

have

have

have

Terrestrial

Marine

Scales

Fur

Feathers

Beetles, Flies

Ibosters, crabs

Fish

Cats,

Penguins

Chicken
Applications of Concept Mapping:

- Assessment tool
- A chapter summary for students and therefore help the students during revision.
- Guide for the teacher during classroom interaction so as to bring out the necessary concepts.
- Organizational guide for students at the start of the chapter to point out the prerequisite concepts.
- Basis for identifying key ideas in the chapter and instructional examples to be given to students.

Steps in Concept Map construction

8) Select about 12 concepts from the biology content material being considered.
9) Write each concept on a separate note card. Lay these cards down on a large sheet of paper.
10) Select a super ordinate (most general) concept to be placed at the top of the map.
11) Arrange the other concepts in a distinct hierarchy under the super ordinate concept
12) Once the concepts have been arranged, draw lines between related concepts and label each linking line with words that characterize the relationship between those concepts.
13) If you wish to cross-link two concepts in different branches of your map, use a dashed line and label their relationship by writing on the linking line.
14) Examples, if they are to be given, should be connected to their source concepts by an e.g. labeled linking line.
Activities

1 a) Use the following concepts to construct a Concept Map on photosynthesis.

Plants, sunlight, water, CO₂, air, energy, leaves, photosynthesis and food.

b) The following is a Concept Map from a student. Study it and identify errors, omissions and misunderstanding of concepts by this student.
You are provided with Manila paper, office glue and cards. Working in your groups make a poster of a Concept Map using appropriate propositions written in the blank cards and the concepts provided below. Display the poster in the classroom.

Concepts:

1) Water, salts and urea
2) Water and carbon dioxide
3) Lungs
4) Water, mineral salts and traces of urea
5) Kidneys
6) Stomata leaf and stem
7) Excretion
8) Plants
9) Skin
10) Cortex, medulla and pelvis
11) Oxygen, carbon dioxide, water, nitrogenous waste and mineral salts
12) Humans

3.0 What are the challenges likely to be encountered when using Concept Mapping?

Notes on Concept Mapping in Biology (for Students)

Introduction

The way the course content in Biology subject taught in schools as presented gives the impression that each subject consists of a series of separate chunks of information. This masks the context of the subject matter and leads to loss of meaning by failing to make the links between related or associated concepts clear. Among the many concerns teachers of
Biology are left to grapple with are the following:

- What is the best way to convey the many concepts that are taught in Biology so that all learners can retain and use the information?
- How can lessons be presented so that they are interconnected and so build upon each other?
- How can science be made meaningful and relevant to the learners?

According to the contextual learning theory, learning occurs only when learners process new information using their own frame of reference, experiences, and responses in a way that makes sense to them. Teachers prepare learning experiences that relate subject matter content to real-world situations. They motivate learners to make connections between knowledge and its applications to the learners’ lives. Thus Biology is taught and learned in the context of daily life, technology, community, or society. Concepts are internalized through the process of discovering, reinforcing and relating.

The burden then rests on the teachers to highlight links in the development of their work, so students can appreciate, Biology as an interconnected body of knowledge. This approach adopts the belief that true knowledge and understanding can be developed in the learner and by the learner, through the transformation of fragmented, compartmentalized bits of knowledge into knowledge of personalized meaning Sham Baugh (1995). The student is required to make conscious effort to:

1. **Identify the key concepts in new knowledge**
2. **Relate these key concepts to concepts in his/her existing knowledge structure**

Concept Mapping is a strategy that requires learners to organize a set of related concepts that make up the content of a lesson. A Concept Map shows relationships between concepts including bi-directional ones. Usually, a Concept Map is divided into nodes and links. Nodes
(often circles or boxes) represent key concepts; links (lines) represent relationships (propositions) between concepts (Edwards & Fraser 1983). The link is represented by an arrow, the direction of which indicates the direction of the relationships. Words are used to label the links in order to depict more explicitly the relationships. The relationship is written on the line.

**Steps in Concept Map construction**

1. Select about 12 concepts from the biology content material being considered.
2. Write each concept on a separate note card. Lay these cards down on a large sheet of paper.
3. Select a super ordinate (most general) concept to be placed at the top of the map.
4. Arrange the other concepts in a distinct hierarchy under the super ordinate concept.
5. Once the concepts have been arranged, draw lines between related concepts and label each linking line with words that characterize the relationship between those concepts.
6. If you wish to cross-link two concepts in different branches of your map, use a dashed line and label their relationship by writing on the linking line.
7. Examples, if they are to be given, should be connected to their source concepts by an e.g. labeled linking line.

NB: see Map Previous pages.

Concept Mapping is a highly flexible tool that can be adopted for use by almost any group of learners. The concepts are written in boxes and linked by labeled arrows. The most inclusive concepts towards the bottom. Where possible, these are anchored with specific examples. While each concept can only appear in one place on the map, it may be linked to any number of others. Finally, it is clear from observation of changes in students’ maps that such structures are in a continual state of flux in an active learner. Therefore, a Concept Map has a
‘limited shelf life’, after which it is simply an historical record. The active use of Concept Maps could be applied to any of four stages of the teaching/learning process: Planning and preparation; Formative learning; Revision/summarizing; Assessment.

**Planning and preparation**

It has been shown that the planning of lesson session can be helped by the process of Concept Mapping to provide a coherent structure to learning materials and making essential links explicit. This is particularly helpful in cases where ‘students’ are learning Biology, as they may appreciate the explanation offered by the various authors of books and other materials.

**Formative learning**

Concept Mapping helps students to gain more unified understanding of a topic and organize their knowledge for more effective problem solving. For ‘holists’, who have a global approach Concept Mapping helps the learners to focus on critical details, whereas, ‘serialists’ can be stimulated to take a wider perspective. However, students who gain most from Concept Mapping are those identified as ‘visual-spatial learners’, who excel when provided with visual representations. Such students reject rote memorization and have need to see how the parts relate to the whole before they can make sense of the isolated ideas typically presented in Biology lessons. This suggests that for teachers to optimize the benefits of Concept Mapping for their students, they first need to be familiar with the students’ prior knowledge and current learning strategies and styles.

**Revision / summarizing**

Concept Maps are excellent summary/revision tools in which large amounts of information are condensed. The creation of such a map forces students to revise actively and to manipulate the information to be learned. Revision by reading through the notes leaves no
evidence of the effort that has been made. With students producing a revision Concept Map to be handed in, the teachers get much more information about each of his/her students’ performance than would be gained from a test mark alone. Mistakes in the test might be picked up as misconceptions or gaps in the Concept Map. Discrepancies between test scores and Concept Map quality might also highlight the relationship between effort, and achievement.

Assessment

Once completed, the Concept Map is a visual representation of a learner’s cognitive structure. It shows the hierarchies and the interconnections of concepts in a lesson. A practical way of generating a Concept Map is to write each term on a piece of paper. The pieces of paper can be rearranged so that when links are drawn the terms are beautifully laid out. When satisfied with the arrangement, the pieces of paper can be pasted on a big sheet and the relationship linking the terms are written on the lines connecting them. This means that the map may vary from person to person. More revealing is the nature of the relationships or links between the concepts defined by each person.

As earlier mentioned, there is no wrong or correct map. There is often more than one appropriate link between a pair of concepts; the layout can vary considerably. However there are some criteria and scoring procedures in evaluating Concept Maps. An example is shown

A number of schools though have supported the use of Concept Maps for summative assessment. They also have suggested evaluating student maps by reference to a teacher-produced or ‘expert map’. Student maps could then be marked according to how many of the propositions in his/her are incorporated.
Examples

Figure 2 (a) an expert map of photosynthesis reduced to a list of 10 propositions
1. Plants absorb water
2. Plants absorb Co$_2$
3. Plants trap sunlight
4. Water is transported to leaves
5. Co$_2$ is found in the air
6. Sunlight is a source of energy
7. Air diffuses into leaves
8. Energy drives photosynthesis
9. Photosynthesis occurs in leaves
10. Photosynthesis produces food

Evaluating a Concept Map

Table 1

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Definition</th>
<th>Scoring Procedure</th>
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<tbody>
<tr>
<td>Concept Recognition</td>
<td>Concepts are objects, events, situations or properties of things that are designated by a label or symbol</td>
<td>Count all concepts that are connected to other concepts by propositions. Score point for each concept</td>
</tr>
<tr>
<td>Grouping</td>
<td>Groupings are ways concepts can be linked or joined together. Three types of grouping are: - Point grouping- a number of single concept emanate from one concept. Open grouping- three or more concepts are linked in a single chain</td>
<td>Point grouping- 1 point for each concept in the group Open grouping- 2 point for each concept in the group</td>
</tr>
<tr>
<td>Hierarchy</td>
<td>Concepts in a map can be represented as a hierarchical structure in which more general and more inclusive concepts are at the top of the map: the specific and exclusive concepts are at the lower end of the map.</td>
<td>Only first concepts are scored for the degree of hierarchy in the map. This is based on the extent concepts are present in the assigned levels. Four points are given to each concept correctly assigned to a level: 2 points for each concepts one level removed from an assigned level; no score for concepts that are two levels removed.</td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Branching</td>
<td>Branching of concepts refers to the level of differentiation among concepts that is to the extent to which more specific concepts are connected to more general concepts.</td>
<td>Score 1 point each branching point, which has at least two statement lines.</td>
</tr>
<tr>
<td>Proposition</td>
<td>Concepts acquired meaning through the relationship between concepts. The relationships are represented by connecting words or phrases written on the line joining the two concepts.</td>
<td>Simple-proposition- score 1 point for each word or phrase: half point for repeated use. Scientific propositions-score 2 points. 1 point for each repeat use.</td>
</tr>
</tbody>
</table>

Like all teaching tools, Concept Mapping is not a panacea; it will suit all learners or all learning situations. Therefore, the following are some of the challenges and/or shortcomings teachers and learners face while using Concept Mapping.

**Challenges / short comings of Concept Mapping**

1. There is no limit as to how many concept boxes teachers and learners (mappers) should use. As a result it may become unmanageable or unclear, as maps are only really useful if they portray a clear representation of the authors’ thoughts.

2. Some learners may rush to conceal some aspects of their understanding and so their maps would not provide ‘total insight’ to the student’s perspective.
3. Concept Maps are in a continual state of flux in an active learner as is demonstrated by observation of changes in learners’ maps even over a short period of time. Therefore, a map that is to be used as the basis for further instruction has a ‘limited shelf life’ after which it is simply an historical record.

4. A Concept Map presented to a class to use as an advance organizer may be viewed as the right answer to simply memorize whereas it is intended to reveal the personal perceptions of the map’s author.

5. If the scorer decides to deduct marks for factually incorrect propositions, the students’ scores reduce to zero if enough incorrect propositions are included, even though some excellent ideas may also be represented.

6. Students usually prefer to be ‘spoon fed’ rather than having to work out problems for themselves, and that most students hate concerned with providing the ‘right answer’ rather than displaying what they do or do not know in a Concept Map or by any other means.

7. Some students may be learning meaningfully already and may be employing strategies similar to Concept Mapping, possibly subconsciously. Therefore overlaying something on a process that they are doing already may be resisted by the learners.

8. It is not sufficient to simply ‘tack on’ a Concept Mapping exercise to a ‘traditionally objectivist’ lesson sequence and hope that the learners will somehow gain some benefit from it. A combination of learning cycles and Concept Mapping is recommended as this provides both the concrete experiences and cognitive structures that are required for meaningful learning to occur.
Conclusion

For Concept Mapping to provide maximum benefit to the learner, it would seem sensible that the mapping activity should be integrated with a variety of other classroom activities. It is not sufficient to imply ‘tack on ‘a Concept Mapping exercise to a ‘traditionally objectivist’ lesson sequence and hope that the student will somehow gain some benefit from it. A combination of learning cycles and Concept Mapping is recommended as this provides both the concrete experiences and cognitive structure that are required for meaningful learning to occur because more generative study strategies produce qualitatively better learning. This is because of the internal connections between idea units and current knowledge. This is a paradigm shift in the focus of future teaching, learning, and assessing away from remembering ‘isolated things’ towards recognition of ‘how students interactively construct the pattern that connects’.

Definition of terms

**Personalized meaning**: is the true knowledge and understanding developed in the learner, and by the learner, through the transformation of fragmented, compartmentalized bits of knowledge

**Graphic organizers**: are visual construction devices that help the students to visualize how major ideas are related to their own prior knowledge, subordinate ideas and associated ideas from other topic areas.

**Concept Mapping**: is a strategy that requires learners to organize a set of related concepts that make up the content of a lesson. A Concept Map shows relationships between concepts including bidirectional ones. Usually, a Concept Map is divided into
nodes and links. Nodes (often circles) represent key concepts; links (lines) represent relationships (propositions) between concepts (Lazing, 1997).

**Visual-spatial learners**: are students who excel when provided with visual representations, reject rote memorizations and take initiative to see how the parts relate to the whole before they can make sense of the isolated ideas typically presented in Biology lessons.

**Expert map**: is a teacher-produced map which show the points a teacher wishes to cover in a particular lesson sequence, and how they interrelate. It may also be used to show a basic framework that a teacher might hope for his/her students to have at the end of a lesson sequence on a topic.

**Paradigm shift**: a fundamental change in approach from the old way of doing something

**Meaningful learning**: is the central idea of the Assimilation Theory of learning in which the student is required to make a conscious effort to identify the key concepts in new knowledge and relate to them to concepts in his/her existing knowledge structures.

**Visual Construction tools**: there are various construction tools or ‘graphic organizers’ available for use in a mathematics and science classroom. Such tools help students visualize how major ideas are related to their own prior knowledge, subordinate ideas and associated ideas from other topic areas. Each of these graphic organizers has its own strengths and weaknesses, but it is Concept Mapping, as developed by Novak (1998) about which the research literature has been consistently positive. In this the student is required to make a conscious effort to identify the key concepts in new knowledge and relate them to concepts in his/her existing knowledge structure.
2.4.5 Challenges / Shortcomings of Concept Mapping

1. There is no limit as to how many concept boxes teachers and learners (mappers) should use. As a result it may become unmanageable or unclear, as maps are only really useful if they portray a clear representation of the authors’ thoughts (Edwards & Frazer, 1983; Derbentseva et al., 2004).

2. Some learners may rush to conceal some aspects of their understanding and so their maps would not provide ‘total insight’ to the student’s perspective (Canas et al., 2005).

3. Concept Maps are in a continual state of flux in an active learner as is demonstrated by observation of changes in learners’ maps even over a short period of time. Therefore, a map that is to be used as the basis for further instruction has a ‘limited shelf life’ after which it is simply an historical record (Briggs et al., 2004).

4. A Concept Map presented to a class to use as an advance organizer may be viewed as the right answer to simply memorize whereas it is intended to reveal the personal perceptions of the map’s author (Canas et al., 2005).

5. If the scorer decides to deduct marks for factually incorrect propositions, the students’ scores reduce to zero if enough incorrect propositions are included, even though some excellent ideas may also be represented (Coffey et al., 2002).

6. Students usually prefer to be ‘spoon fed’ rather than having to work out problems for themselves, and that most students hate concerned with providing the ‘right answer’ rather than displaying what they do or do not know in a Concept Map or by any other means (Edwards & Frazer, 1983).

7. Some students may be learning meaningfully already and may be employing strategies similar to Concept Mapping, possibly subconsciously. Therefore overlaying
something on a process that they are doing already may be resisted by the learners (Briggs et al., 2004).

8. It is not sufficient to simply ‘tack on’ a Concept Mapping exercise to a ‘traditionally objectivist’ lesson sequence and hope that the learners will somehow gain some benefit from it. A combination of learning cycles and Concept Mapping is recommended as this provides both the concrete experiences and cognitive structures that are required for meaningful learning to occur (Beirute & Mayorga, 2004).

The researcher therefore clarifies that for Concept Mapping to provide maximum benefit to the learner, it would seem sensible that the mapping activity should be integrated with a variety of other classroom activities. Nevertheless, this is a paradigm shift in the focus of future teaching, learning, and assessing, away from remembering ‘isolated things’ towards recognition of ‘how students interactively construct the pattern that connects various bits of information in order to generate knowledge. Furthermore, a study by Namasaka, Mondoh and Keraro (2013) revealed female students achieve higher scores on test compared to their male counterparts when both are exposed to Concept Mapping technique. The results also showed that female students are more motivated to learn Biology compared to the male students. However, the difference in levels of motivation were not statistically significant.
References


http://inspiration.com/home.cfm


APPENDIX V: THE ENZYME ACTION DISCUSSION

1. What are Enzymes? Biocatalysts that speed up chemical reaction.

Enzymes are globular proteins with catalytic properties, ie they increase the rate of reaction by lowering its activation energy (the minimum energy needed to initiate a reaction) the reagents or substrates, fit into the active suite of the enzymes then react to form product easily. An enzyme is an organic catalyst.

2. Properties characteristics of enzymes.

a) All enzymes are globular proteins, spherical in shape
b) Control biochemical reactions in cells
c) They have the suffix “ase”
d) Extracellular enzymes act outside the cell (eg digestive enzymes)

3. How enzymes catalyse a reaction

Enzymes are catalysts speed up chemical reaction by:

- Reduce activation energy required to start a reaction between molecules
- Substrate (reactants) are converted into products
- Reaction may not take place in absence of enzymes (each enzyme has a specific catalytic action)
- Enzymes catalyse a reaction at max. rate at an optimum state
- Enzymes are sensitive to heat
- Enzymes are sensitive to pH
4. (a) The Lock and Key Hypothesis was proposed by a scientist, Emil Fischer. According to Emil Fischer “The lock is the equivalent to that of an enzyme while the key is portrayed as the substrate”

(b) In this hypothesis, the active site of the enzymes is exactly complementary to the substrate, and the reaction proceeds as below.

The substrate is the “key” which fits exactly into the “lock” of the enzyme

- Only one substrate (key) can fit into the enzyme’s active site (lock)
- Both structures have a unique shape

(c) To further support his statement, he gave the following ideas:

“Like an enzyme, the lock can be reused many times as it remains chemically unchanged.

At the end of the reaction. Also, the fact that reactions occur only at the active site, or binding site, is showed as the key only being able to open the lock only at the keyhole, not anywhere else” Now this is where you have to THINK and question the statement. Why?

(d) Well, now look; everyone knows that it is the lock that opens and changes its basic Structure after the key has been inserted into it. Now considering the enzymes, it is not altered and does not change its shape or structure after the reaction. The substrate on the other hand loses its primary structure, and is either broken down or converted into any new form.
(e) **THEORY CONFLICT!!!**

Now, if we refer to the enzymes as the lock, well then according to the above explanation, the theory is completely void, because a lock changes shape every time we insert a key into it! While on the other hand, the key remains unchanged! It’s not like we have to purchase a key every now and then from the hardware store to open the same old lock!

By looking at the previous diagram, you will see that it is the SUBSTRATE that loses its original form and not the ENZYME! So, logically, you cannot refer to the Enzymes as the lock because we can see, the enzymes structure remains the same throughout the reaction.

5 (a) Induced Fit Theory

- Substrate binds to the enzymes active site.
  - The shape of the active site changes and moves the substrate closer to the enzyme.
  - Amino acids are moulded into a precise form
  - Enzyme wraps around substrate to distort it
- This lower the activation energy
- An enzyme-substrate complex forms – fast reaction.
- $E + S \rightarrow P + E$

(b) Induced fit theory of enzymes action is a modified version of the lock and key theory.
Here the active site of the enzyme is not quite complementary to the substrate. However when the substrate enters the active site, its shape is altered so that the substrate now fits exactly.

(a) An active site is the part of an enzyme that directly binds to a substrate and carries a reaction. It contains catalytic groups which are amino acids that promote formation and degradation of bonds. By forming and breaking these bonds, enzymes and substrate interaction promotes the formation of the transition state structure. Enzymes help a reaction by stabilizing the transition state intermediate. This is accomplished by lowering the energy barrier or activation energy – the energy that is required to promote the formation of transition state intermediate. The three dimensional cleft is formed by the groups that come from different part of the amino acid sequences. The active site is only a small part of the total enzyme volume. It enhances the enzyme to bind to substrate and catalysis by many different weak interactions because of its no polar microenvironment. The weak interactions include the Van der Waals, hydrogen bonding and electrostatic interactions. The arrangement of atoms in the active site is crucial for binding specificity. The overall result is the acceleration of the reaction process and increasing the rate of reaction. Furthermore, not only do enzymes contain catalytic abilities, but the active site also carries the recognition of substrate.

(b) The enzyme active site is binding site for catalytic and inhibition reactions of enzyme and substrate; structure of active site and its chemical characteristic are specific for the binding of a particular substance. The
binding of the substrate to the enzyme causes changes in the chemical bonds of the substrate and causes the reactions that lead to the formation of products. The products are released from the enzymes surface to regenerate the enzymes for another reaction cycle.

7 (a) **Enzymes Groups:**

i) Oxidoreductases catalyse all oxidation and reduce reaction (i.e reactions that involve the transfer of oxygen and hydrogen). Dehydrogenase and oxidase are both oxidoreductases.

ii) Transferases catalyze the transfer of chemical/functional groups between substances, e.g transaminase and phosphorylase.

iii) Hydrolases catalyse hydrolysis reactions e.g lipases, carbohydrases and proteases.

(b) Enzyme is not used up in the reaction (unlike substrates)

8 (a) **Catabolic reactions:** Any reaction where large molecules are broken down into smaller ones. Enzymes can catalyse the reaction in the reverse.

**Anabolic Reactions:** Any reaction where smaller molecules are built up to make large ones.

Together, anabolic and catabolic reactions are classed as metabolic reactions (hence metabolism)
(b) Tip to remember which way round anabolic and catabolic go. Remember the anode positive and anabolic is building up (a+) whilst the cathode is negative and catabolic is breaking down (c-)

9 Factors affecting enzyme activities,

1) Enzymes specificity to particular reactions.

2) Effects of temperature on enzyme activity: the working temperature of enzymes is 0-60°C with optimum temperature at -40°C (body temperature)

![Graph showing enzyme activity vs temperature]

If the temperature is too high, there is enough energy to break down the tertiary structure of the enzymes *the weak hydrogen bonds that determine the shape of the molecule are broken). This alters the shape of the active site so that the substance no longer fits; the enzymes is said to be denatured.

If the temperature is too low, the substrate molecules simply do not have enough energy to move into the site and be catalyzed.

3) Effect of pH on enzyme activity: The optimum pH for each enzyme is different depending on where in the body it is supposed to work (pepsin works best in acid conditions and is found in the stomach, pepsin work
The graph has the same form as the one for temperature.

pH depends on the concentration of $H^+$ and $OH^-$ ions (see Chemistry section for more details on pH). If the concentration of $H^+$ or $OH^-$ is too high, the presence ions will alter the tertiary structure of the protein by breaking the weak hydrogen bonds that determine the shape of the molecule, once again altering the shape of the active site so that the substrate no longer fits.

4) **Effects of Substrate concentration on enzyme activity**

The rate of enzyme activity increases with increase in substrate concentration up to a point called plateau where the active site is saturated with substrate.
5) **Effect of enzyme concentration on enzyme activity**: Graph similar to above as long as excess substrate is present, the reaction rate increases with enzyme concentration. If there is no excess, no further increase is possible (there is simply no more substrate available to be catalyzed no matter how much more enzyme is added)

![Graph of Reaction Rate vs. Enzyme concentration](image)

Typically, the concentration of substrate will be about 1000 times the concentration of enzyme.

6) **Effect of inhibitors**

a) **Non competitive inhibition**: This is where an inhibitor molecule binds to the enzyme away from the active site so that the substances can no longer fit and the enzyme away from the active site so that the substance can no longer fit and the enzyme is inactivated. (effectively the concentration of enzyme is reduced). Cyanide is a non-competitive inhibitor; it inhibits cytochrome oxidase, preventing the transfer of electrons in respiration.

b) **Competitive inhibition**: In this case, the inhibitor molecule is of a similar shape to that of the substrate, so substrate and inhibitor compete for the active site. When the inhibitor occupies active sites, it decreases the probability that enzyme substrate complexes will form. Malonate is a
competitive inhibitor that inhibits succinic dehydrogenase (competes with succinate molecules)

c) **End product inhibition**: imagine a series of enzyme catalyzed reactions. 

A→B→C→D

If excess D (end product) is formed, it non-competitively inhibits the enzyme that converts A to B (must be a non competitive inhibitor otherwise the system wouldn’t work at high concentrations of A). This effectively stops the production of B, and thus C and D. As no more D is being made, the excess D will eventually be used up. When this happens, the inhibition on the A→B reaction is lifted, and the system starts up again. This is an example of **negative feedback** and is useful in ensuring that endless quantities of unnecessary end product are not produced.

Enzymes may require a non-protein part (i.e cofactor = inorganic) or co-enzyme = (organic component) in order to function well.

(d) **Enzyme Cofactors** are non-proteins whose presence is essential for the functioning of some enzymes. There are three main types:

a) **Activators** are inorganic.mineral ions that combine with the enzyme or substance, probably to make the formation of the enzyme-substrate complex easier. Salivary amylase require chloride ions whilst thrombokinase needs Ca\(^{2+}\) ions as activators.

b) **Co-enzymes** are organic molecules. NAD is a co-enzyme which picks up excess hydrogen ions, thus maintaining pH for the dehydrogenase enzyme.
c) **Prosthetic groups** are organic molecules that are physically bound to an enzyme, e.g. the haem molecule is bound to catalase.

**Uses of enzymes**

i) **Enzymes in biotechnology**: enzymes can be used for the production and detection of certain compounds because, unlike inorganic catalyst, they are specific and do not produce harmful by-products. They can also work at low temperatures and pressures as well as a range of pH values (more cost effective than an inorganic catalyst which might need a high temperature in order to work).

ii) **Biosensors**: enzymes can be used to detect specific compounds. The example used here is the analysis of glucose:

\[
\text{B-D-glucose} + \text{O}_2 \rightarrow \text{gluconic acid} + \text{H}_2\text{O}_2
\]

\[
\text{DH}_2 + \text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{D (Coloured Compound)}
\]

The first reaction is catalysed by glucose oxidase, the second by peroxidase. Obviously the appearance of the coloured compound D indicates that glucose is present in the original sample.

iii) **Thermostability**: Some enzymes are altered so that they will be stable at higher temperatures. For example, sustilisin is modified for use in detergent so that it will work effectively at 60°C instead of being denatured important if you want to do a 60°C wash.

iv) **Immobilization of Enzymes**: the enzyme is attached to an inert material e.g. a membrane or ceramic/polymer gel. Reactant can now be passed...
over the enzyme almost continuously whilst contamination of products is prevented. Cost-effectiveness is increased as the enzymes can be quickly and easily recovered.

v) Production of fructose by enzymic hydrolysis of starch: demonstrates one of the many industrial uses of enzymes.

1) First amylase is used to convert starch into dextrin

2) Saccharifying enzymes are now used to break dextrin down into glucose.

LABORATORY STUDENT EXPERIMENTS

PRACTICAL ACTIVITY I

To investigate the factors affecting enzymes activities.

a) Effect of temperature on enzyme activity.

Requirement

Six clean test-tubes, white tile, test-tube holder, a dropper, distilled water, Benedict’s solution, iodine solution, water bath maintained at 37°C and 50°C, source of heat, thermometer, measuring cylinders, labels, 6 cm³ of amylase solution and soluble starch powder.

PROCEDURE

I) Label three test-tubes A, B AND C

II) Into test-tube A and B, add 3 cm³ of starch solution

III) Into test-tube A,B and C add 2 cm³ of amylase solution

IV) Place test-tube B in the water bath maintained at 50°C for 30 minutes
V) Place the remaining test-tubes A and C in the water bath maintained at 30° for 30 minutes

VI) After the 30 minutes, test for starch and reducing sugars on the contents of each test-tubes. Record your results.

Study Questions

Which of the test tubes showed:

i) Presence of starch:

ii) Presence of reducing sugars?

Explain your results

iii) What was the reason for maintaining the test-tubes at 37°C?

iv) Treating test-tube C to a temperature of 50

b) Effect of pH on enzyme activity:

Requirements

Water bath kept at 37°C, egg albumen suspension, 2M of hydrochloric acid, 2M sodium hydroxide three test-tubes, 5 cm³ of 1% pepsin solution, means of heating and measuring cylinder.

Procedure

i) Stir the white of an egg (the albumen) with 500 cm³ tap water. The mixture is boiled and filtered through glass wool to remove large particles.

ii) Using a measuring cylinder, place 2 cm³ of the cloudy suspension of egg albumen into each of the two test-tubes labeled A, B and C

iii) Add 1 cm³ of the 1% pepsin solution to each of the three test tubes A, B and C
iv) To the contents of test-tube A add three drops of the 2M hydrochloric acid, to B add three drops of distilled water, to C add three drops of the 2M sodium hydroxide solution.

v) Incubate the test tubes for 10 minutes in a water bath kept at 37°C

vi) Examine the test tubes every two minutes, noting the cloudiness of the contents. After 10 minutes remove the test tubes and place them in a test-tube rack.

vii) Tabulate your results in the following format.

<table>
<thead>
<tr>
<th>Test-tube</th>
<th>OBSERVATION OF CLOUDINESS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 MINS</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
<tr>
<td>C</td>
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</tbody>
</table>
Practical Activity 2

To investigate the presence of catalase in living tissues.

Catalase is an enzyme present in living tissues of plant and animals. Its role in living tissues is to break down hydrogen peroxide ($\text{H}_2\text{O}_2$) produced during cellular metabolism. Hydrogen peroxide is a highly toxic chemical substance which should not be allowed to accumulate in the tissues. If it were to accumulate in the tissues, it would interfere with cellular metabolism. Enzyme catalase breaks it down into water and oxygen which are non-toxic substances.

Requirements

Fresh liver, fresh kidney, fresh muscle, potato, hair seeds, leaves, hydrogen peroxide, four test-tubes, wooden splints means of heating, scalpel blade, measuring cylinder (10 cm$^3$) and labels.

Procedure

i) Label five test tubes A, B, C, D and E
ii) Measure 2 cm$^3$ of hydrogen peroxide and put in test-tube A. Repeat the same procedure for test-tubes B, C, D and E
iii) Cut a small piece of the liver and place it in test-tube A. Record your observation
iv) Immediately, introduce a glowing splint into the mouth of the test-tube. Record your observations.
v) Repeat step 3 using muscle tissue, kidney, potato and finally a small amount of hair.
vi) Record your observations noting any differences. Explain your observations.
vii) Repeat step 3 using boiled liver. Make sure that the liver is thoroughly boiled for about 5 minutes. Record your observations and account for the differences with unboiled liver.

**Concepts to be used for mapping**

The concepts include, Enzymes, nomenclature, inhibitors, co-factors, coenzymes, prosthetic groups, inorganic ions, substrate, concentration, temperature, saliva, amylase, digestion, enzyme action, competitive inhibition, non-competitive inhibition, product, activation energy, Ph, catalase, Lipase, proteases, carbohydrases, Active site, Apo-enzymes, Hydrolysis, catalysis, Hydrogen peroxide and lock and key.
APPENDIX VI: Data on Raw scores

Group 1 a

<table>
<thead>
<tr>
<th>No.</th>
<th>ADM NO.</th>
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## APPENDIX VII: OLD CATEGORY OF NATIONAL SCHOOLS

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APPENDIX VIII: Distribution of Old Category National Schools

KEY
1 Nyanza
2-5 Rift Valley
6-10 Nairobi
11-18 Central Kenya
Appendix IX: Marking Scheme for Post-test Biology Achievement Test (BAT)
Award four marks for each correct answer up to a maximum of 100 marks

1. c
2. e
3. d
4. d
5. c
6. d
7. a
8. c
9. c
10. d
11. c
12. e
13. a
14. a
15. c
16. e
17. a
18. e
19. a
20. a
21. a
22. d
23. d
24. d
25. b
Appendix X: Marking scheme for Biology Knowledge Retention Test (BKRT)

1. e
2. a
3. a
4. c
5. e
6. a
7. a
8. c
9. c
10. d
11. c
12. e
13. a
14. a
15. a
16. d
17. c
18. e
19. d
20. d
21. d
22. d
23. c
24. d
25. b
Appendix XI: Marking Scheme for Pre-test BAT

1. b
2. e
3. a
4. c
5. d
6. d
7. c
8. c
9. c
10. c
11. a
12. d
13. e
14. d
15. d
16. d
17. a
18. e
19. a
20. a
21. a
22. c
23. a
24. e
25. d
Appendix XII: Concepts for scoring Concept Maps

Refer to table 6 on the criteria for scoring concepts which are expected to be incorporated on the Concept Maps

1 enzymes
2 nomenclature
3 inhibitors
4 co-factors
5 co-enzymes
6 prosthetic groups
7 inorganic ions
8 substrate
9 concentration
10 temperature
11 saliva
12 amylase
13 digestion
14 enzyme action
15 competitive inhibitors
16 non-competitive inhibitors
17 product
18 activation energy
19 PH
20 Catalase
21 Lipase
22 Protease
23 Carbohydrates
24 active site
25 Apo-enzyme
26 Hydrolysis
27 Catalysis
28 Hydrogen peroxide
29 Lock and key hypothesis
Appendix XIII: Sample Letter to Request Permission for Data Collection

To: The Principal,  
........................ School,  
P.O BOX .....................,  
......................................  
FROM Researcher,  
Pwani University,  
P.O BOX 195-80108,  
Tel; 0722228620,  
Email;  
namasakafred@gmail.com  

Date: 15/03/2013

Re: Request To Collect Data in Your School

The researcher working on the research titled “Effects of Sequential Teaching Methods on Learners Achievement, Retention and Transfer of Knowledge in Biology by Secondary School Students in Kenya.” Wishes to collect data in selected old category national schools in Kenya. Your school has been sampled for the study scheduled to be done between May 2013 and July 2013. The researcher will only be interested in form one students taking Biology in the school curriculum. The researcher will also need to train the teachers who will be involved in the study and further train the students on Concept Mapping technique. The teachers in Biology will be provided with the teaching manual (See Appendix V), and the learning resources for the study. They will also be given tools for data collection. The purpose of the study is to evaluate effectiveness of different sequences of teaching methods. I will shed more light on the nature of the research when I come in person to train the teachers and learners.

The purpose of this letter is to request you to allow the researcher to conduct the study in your school during the second term of 2013. Please find attached a copy of the research authorisation from the National Council of Science and Technology.

I remain looking forward to your positive response and kindly do so in good time.

Yours faithfully

Fred W. Namasaka  

Researcher & Ph.D Candidate, Pwani University
NCST/RCD/14/013/272

Fred Wafula Namasaka
Pwani University College
P.O.Box 195-80108
Kilifi.

RE: RESEARCH AUTHORIZATION

Following your application dated 15th March, 2013 for authority to carry out research on "Effects of sequential teaching methods on achievement, retention and transfer of knowledge of Biology by secondary school students in Kenya," I am pleased to inform you that you have been authorized to undertake research in selected Districts for a period ending 31st December, 2013.

You are advised to report to the District Commissioners and the District Education Officers of the selected Districts before embarking on the research project.

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

DR M.K. RUGUTT, PhD, HSC.
DEPUTY COUNCIL SECRETARY

Copy to:

The District Commissioners
The District Education Officers
Selected Districts.

"The National Council for Science and Technology is Committed to the Promotion of Science and Technology for National Development."
THIS IS TO CERTIFY THAT:

Prof. Dr. Mr. Mrs./Miss Institution
Fred Wafuva Namasa of [Address] Pwani University College
P.O. Box 109-80108, Kilifi

has been permitted to conduct research in

Location
Selected Districts
Selected Provinces

on the topic: Effects of sequential teaching methods on achievement, retention and transfer of knowledge of Biology by secondary school students in Kenya for a period ending 31st December, 2013.

Applicant’s Signature

Signature

National Council for Science and Technology

Research Permit No. NCST/RCD/14/01/327
Date of issue 25th March, 2013
Fee received KSH. 2,000
You must report to the District Commissioner and the District Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit.

The Government officers will not be interviewed without prior appointment.

No questionnaire will be used unless it has been approved.

Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.

You are required to submit at least two (2) four (4) bound copies of your final report for Kenyans and non-Kenyans respectively.

The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice.

CONDITIONS—see back page.

REPUBLIC OF KENYA

RESEARCH CLEARANCE PERMIT

GPK605535m10/2011